Technical Report Documentation Page

1. REPORT No.

III-ED-38-B

2. GOVERNMENT ACCESSION No.

3. RECIPIENT'S CATALOG No.

4. TITLE AND SUBTITLE

Report on Slide Investigation at Emerald Bay on Road III-ED -38-B Station 243+- to 250+-

5. REPORT DATE

December 1957

6. PERFORMING ORGANIZATION

7. AUTHOR(S)

Smith, T.W. and G.D. Ralph

8. PERFORMING ORGANIZATION REPORT No.

III-ED-38-B
Lab Auth. No. 2198-20-T

9. PERFORMING ORGANIZATION NAME AND ADDRESS

State of California
Department of Public works
Division of Highways
Materials and Research Department

10. WORK UNIT No.

11. CONTRACT OR GRANT No.

12. SPONSORING AGENCY NAME AND ADDRESS

13. TYPE OF REPORT & PERIOD COVERED

14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT

After several preliminary discussions of the various aspects of the slide at Emerald Bay on road III-ED-38-B a teletype from Mr. A.S. Hart to Mr. F.N. Hveem dated July 1, 1957, authorized the Materials and Research Department to proceed with the necessary exploration in the slide area.

A slide had occurred between Station 245 and Station 250 in the late winter of 1953. The approximate limits of this slide are shown on the attached plan Sheet No. 2. Another slide occurred between December 25, 1955, and January 1, 1956. The slide mass covered or obliterated the road for several hundred feet. The approximate limits of this slide are also shown on the plan. At the time of the slide the area was covered with snow; hence, a lot of the details of the slide were not completely discernible until after the snow melted. A large mass of debris moved as a result of the slide. A considerable quantity of boulders, as well as disintegrated granite, top soil and vegetation, including some rather large trees, moved all the way to the lake which is several hundred feet below the road. The mass of soil and rock within the slide was badly disturbed and sheared. It was difficult to estimate the distance that portions of the mass had moved but it was evident that there had been considerable movement. The upper edge of the slide was well defined by the scarp; however, the upper part of the slide broke further back at least once during the spring of 1956. The north edge of the slide was well defined, but the south edge was rather obscure, especially near the road.

17. KEYWORDS

III-ED-38-B
Lab Auth. No. 2198-20-T

18. No. OF PAGES:

46

19. DRI WEBSITE LINK

http://www.dot.ca.gov/hq/research/researchreports/1956-1958/59-24.pdf

20. FILE NAME

59-24.pdf

STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS

REPORT

on

SLIDE INVESTIGATION AT EMERALD BAY

on

ROAD III-ED-38-B

STATION 243± TO 250±

December 17, 1957

MATERIALS & RESEARCH DEPARTMENT

State of California
Department of Public Works
Division of Highways
Materials and Research Department

December 17, 1957

III-ED-38-B
Lab Auth No. 2198-20-T

Mr. Alan S. Hart
District Engineer
Division of Highways
Marysville, California

Dear Sir:

Submitted for your consideration is:

REPORT

on

SLIDE INVESTIGATION AT EMERALD BAY

on

ROUTE 38

ROAD III-ED-38-B

STATION 243± TO 250±

Study made by........................Foundation Section
Under general supervision of.........A. W. Root
Work supervised by...................G. V. Stafford
Report prepared by...................T. W. Smith
G. D. Ralph

Very truly yours,

F. N. Hveem
Materials & Research Engr.

Attach
cc: JWTrask :TLSommers
JCWomack :HFSherwood
GLangsner
CHamma
JALegarra
FWPanhorst
Dist. Design Dept.-2

Authority

After several preliminary discussions of the various aspects of the slide at Emerald Bay on road III-ED-38-B a teletype from Mr. A. S. Hart to Mr. F. N. Hveem dated July 1, 1957, authorized the Materials and Research Department to proceed with the necessary exploration in the slide area.

History

A slide had occurred between Station 245 and Station 250 in the late winter of 1953. The approximate limits of this slide are shown on the attached plan Sheet No. 2. Another slide occurred between December 25, 1955, and January 1, 1956. The slide mass covered or obliterated the road for several hundred feet. The approximate limits of this slide are also shown on the plan. At the time of the slide the area was covered with snow; hence, a lot of the details of the slide were not completely discernible until after the snow melted. A large mass of debris moved as a result of the slide. A considerable quantity of boulders, as well as disintegrated granite, top soil and vegetation, including some rather large trees, moved all the way to the lake which is several hundred feet below the road. The mass of soil and rock within the slide was badly disturbed and sheared. It was difficult to estimate the distance that portions of the mass had moved but it was evident that there had been considerable movement. The upper edge of the slide was well defined by the scarp; however, the upper part of the slide broke further back at least once during the spring of 1956. The north edge of the slide was well defined, but the south edge was rather obscure, especially near the road.

A rather large quantity of slide material was removed during the summer of 1956. The road was closed during this period and the slide material was pushed toward the lake, starting in the upper part of the slide. It was not anticipated that all of the slide material would be removed. It was not possible by visual inspection to determine the quantity of slide material that was left in place. As the excavation was being made it was not known whether the road had actually been moved out by the slide or had merely been covered. There had actually been very little movement of the road itself, but the pavement had been destroyed by the mass of slide that had moved over it.

Purpose

It was evident when the slide had been removed and the road opened to traffic, that some slide material was in a very precarious, if not dangerous position, above the road. One of the purposes of this exploration was to determine the quantity of slide material that would be necessary to remove to produce a stable slope. This question was further complicated by the proposal that this road should be made an all weather road. Since the present slide face is free of trees, snow slides will be very common to the area, and snowsheds would be necessary in the denuded area.

Consideration has also been given to the possibility of constructing a bridge at the entrance to Emerald Bay. This would require several miles of new alignment. In order to make an economic comparison between the bridge and improvement of the existing road one of the unknown and relatively expensive items was the cost of correcting the slide at Emerald Bay.

The more specific purpose of this investigation was to determine the quantity and condition of slide material still in place, to determine the character and adequacy of the material that underlies the slide mass, and to secure boring data to amplify or correlate the visual characteristics of the slide and adjacent topography.

Exploration

Four vertical borings and seven horizontal borings were made between July 15 and October 1, 1957. The locations of these borings are shown on the attached plan, Sheet No. 2.

Shortly after the borings were started a consulting geologist, Dr. Arthur B. Cleaves, made a field investigation of the landslide area. A copy of his report dated July 28, 1957, is attached. At the time of his field review one vertical boring, R-1, at roadway had been completed, and an additional boring, R-2, was being made on a bench approximately 130 feet above the roadway. Prior to that time consideration had been given to the possibilities of exploration with horizontal borings. Dr. Cleaves was concerned with boring data, particularly "across both the fault planes and the master joint pattern with its localized crush zones," (Item 12-ADDITIONAL EXPLORATION - Dr. Cleaves report). These data could probably best be obtained from horizontal or inclined borings. On July 30, 1957, the first of three horizontal (inclined downward 14%) borings from roadway were started. Toward the latter part of the exploration four borings were made that were inclined upward from 12% to 20%. One of these borings was made from roadway and the other three were made from benches in the slide above the roadway. These borings were made primarily to determine the depth or thickness of the slide material.

The actual drilling operations were very difficult. The slope is very steep. There was some danger from falling rocks as well as an element of risk involved in manipulating the equipment on the narrow benches above roadway. The material was difficult to drill. The material will be described in more detail later and the following paragraph will describe the drilling difficulties.

The drilling equipment used on the vertical borings was a Concore Drill. Bits for this phase of the exploration were small diameter rotary rock bits and limited use of diamond plug bits. Coring was done with AX and NX double tube core barrels equipped with diamond bits. The horizontal borings were made with a McCarthy Rock Boring Machine and a California Horizontal Drill and in general the same type of bits and barrels as were used in the vertical borings. Casing equipped with diamond cutting shoes was used to a very limited extent in the badly disintegrated material. In the earlier phases of the drilling air was used as a circulating medium. For the most part no returns were obtained, i.e., the cuttings and air were blown out through fissures, joints or voids in the formation. In the later phases of the drilling water was used as a circulating medium. Returns were sporadic but considerably better than they had been with air. When the change was made from drilling with air to water, there was great reduction in bit wear, the rate of drilling was much faster, and the recovery was improved. On the whole the drilling was much more successful with water than it had been with air.

Description

The slide mass consisted of granite that had weathered or disintegrated to sand sizes mixed in a loose mass with granite fragments in various states of weathering or disintegration, from fresh to decomposed. The material beneath the slide is similar except it is largely in-place. The actual contact between the slide material and the in-place material was not determined in any boring. There is a progression to fresher granite with depth. There are numerous joints and fractures in the formation. The joints vary in spacing from a few inches to several feet but in general spacing of several inches to a foot or two is more nearly typical. This jointing shows well in the attached photographs of all of the cores.

The following tabulation describes the material by borings. More detailed descriptions of the material from the various borings are shown on the attached sections, Sheets 3 to 6.

Description of Material by Borings

R-1 Vertical boring, at roadway, depth 30'.

Generally the upper sixteen feet of the material was badly broken or decomposed granite. The remaining fourteen feet was a moderately hard fractured and jointed granite.

R-2 Vertical boring, 125' above roadway, depth 90'.

The upper forty feet of material was composed of badly broken granite with considerable loose decomposed granite. Below forty feet the material appears to be in-place fractured and jointed granite with layers (2" to 6") of decomposed granite.

R-3 Horizontal boring, -14% grade, at roadway, depth 78'.

The material appears in-place, being fractured and jointed with some weathering or decomposition in the first twenty-five feet.

R-4 Vertical boring, 130' above roadway, depth 31'.

The material varied from loose broken and decomposed granite to moderately hard fractured granite.

R-5 Horizontal boring, -14% grade, at roadway, depth 57'.

The material from this boring appeared to be in-place fractured and jointed granite with layers of decomposed granite.

R-6 & R-7, Vertical borings 130' above roadway, depths 17' & 12'.

These two borings were discontinued at shallow depths because of drilling difficulties.

R-8 Vertical boring, 130' above roadway, depth 45'.

The first twenty feet of this boring was badly fractured granite with the remaining twenty-five feet of material being a moderately hard fractured and jointed granite with layers of decomposed granite.

R-9 Horizontal boring, -14% grade, at roadway, depth 89'.

The material from this boring was a moderately hard fractured and jointed granite with layers of decomposed granite. Slickensides were found on the fracture planes at approximate depths of twenty-eight and thirty-five feet. It appears that the magnitude of the displacement of material was slight.

R-10 Horizontal boring, +15% grade, 130' above roadway, depth 161'.

The first fifty feet alternated between moderately hard granite and decomposed granite. From fifty to eighty feet the material was predominately decomposed granite of sand sizes. From 80' to 130' the material was a badly fractured granite with considerable degree of decomposition. In the remainder of the boring the granite was moderately hard fractured and jointed.

R-11 Horizontal boring, +17% grade, at roadway, depth 95'.

The boring was similar to the other three (R-3, 5, & 9) horizontal borings made at roadway with the exception that the material showed a greater degree of decomposition.

R-12 Horizontal boring, +20% grade, 130' above roadway, depth 59'.

Although this boring was only seventy feet south of boring R-10 the material was relatively fresh granite with some fractures and joints.

R-13 Horizontal boring, +12% grade, 400' above roadway, depth 92'.

The first forty and the last twenty feet of this boring was a moderately hard fractured and jointed granite with the intermediate material being badly fractured and moderately decomposed.

The attached photographs show the general character of the granite as well as show the jointing, fractures, and shear zones. These photographs also give a good graphic illustration of the percentage of recovery.

Conclusions

The report of Dr. Cleaves, dated October 3, 1957, is his resume of the results of the investigation that has been made at this slide.

As had been suspected, there is considerable slide debris throughout the slide area. The depth varies appreciably as shown by visual inspection and the boring data. There are some areas at the north edge of the slide where stable in-place granite is exposed. Boring data indicate that in other areas the slide material may be 30 to 60 feet deep. The average depth of slide material is probably in the order of 20 to 30 feet deep, and according to Dr. Cleaves estimates that it might be necessary to remove an average of 15 feet in order to construct snow sheds.

It should be noted that the stability of the slide as a whole is probably no better now than before the slide occurred. It is true that a relatively large mass of slide material was removed, which has slightly reduced the driving force that caused the slide. However, it is doubtful if this factor compensates for the loss in strength that occurred in the slide and in the granite beneath the slide as a result of shearing along joints and faults and even the development of shear zones in the granite mass. It is believed that it is merely a matter of time until the slide will move again. It might be soon or it might be several years in the future, but with the proper combination of moisture, snow fall, seismic activity and other factors the slide will move again. It would be necessary to remove the major portion of the slide material in order to alleviate this potential slide hazard.

We concur with Dr. Cleaves as to costs, risks, and other factors involved in constructing a stable cut and a snow shed through the slide. The cost of the construction would approach if not equal the cost of a tunnel, and there would be a grave risk that the snow shed could not be constructed and maintained in the "chute" area in the north portion of the slide. Hence the construction of a cut and snow shed is not recommended.

It is believed that a tunnel can be constructed and maintained without excessive risks. The north portal of the tunnel would be in stable fresh granite outside of the slide area. The main part of the tunnel would be far enough under the slide to be in fresh stable granite that is relatively unaffected by the slide. The south portal of the tunnel would be in badly weathered granite outside of the actual slide and would require heavy reinforcing and considerable care in construction. This department concurs with Dr. Cleaves' opinion that if an all-weather road is to be constructed and maintained along the present alignment, the construction in the slide area should consist of a tunnel.

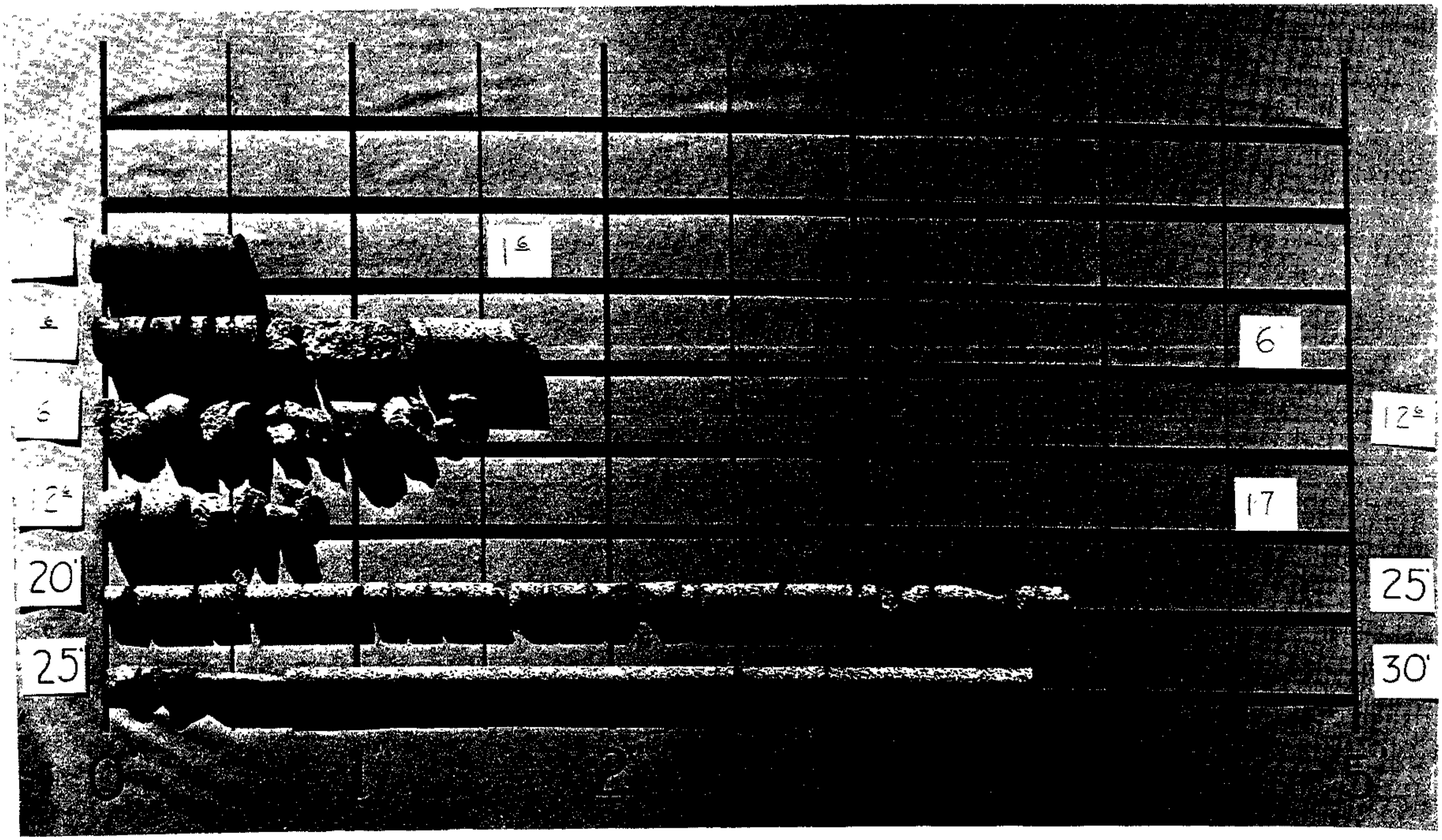
No borings were made on the low level bridge route. Rather cursory visual inspections of this line were made on several occasions. On the basis of these inspections we concur with Dr. Cleaves that "putting aside all other considerations except those of engineering practicability and highway maintenance this is unquestionably the better route." Other considerations such as finances and the fact that the bridge route together with several miles of road would all have to be constructed before any part of it could be used, enter into a decision between a bridge and use of the existing route.

It does not appear desirable to try to improve the existing road for the first mile or two north of the slide to four lanes. To do so would require undercutting terrain that would be subject to slides.

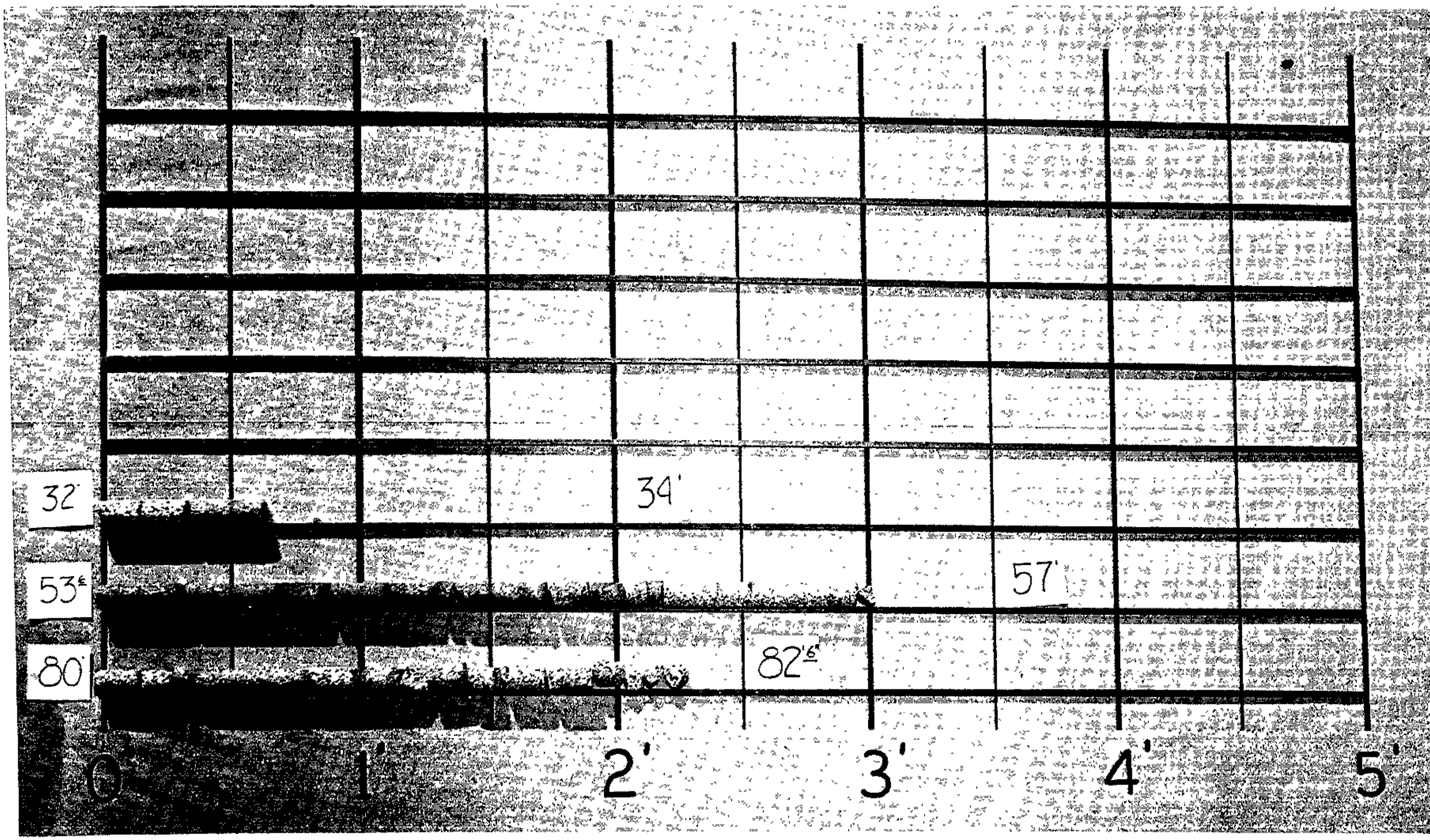
Recommendations

It is believed that a study should be made of the costs, benefits, risks, and other factors involved in the two possible route locations, (1) the present route of the highway through the Emerald Bay Slide and (2) the low-level bridge route. In considering the present route through the slide it is believed inadvisable to attempt to construct and maintain an all-weather road with a cut and snow shed at the slide. It is our opinion that if an all-weather road is required the construction in the slide area should be a tunnel. It is not considered practical or possible to maintain the present road open to traffic throughout the winter. It would be difficult if not impossible to keep open and would constitute a serious hazard to maintenance personnel and the traveling public.

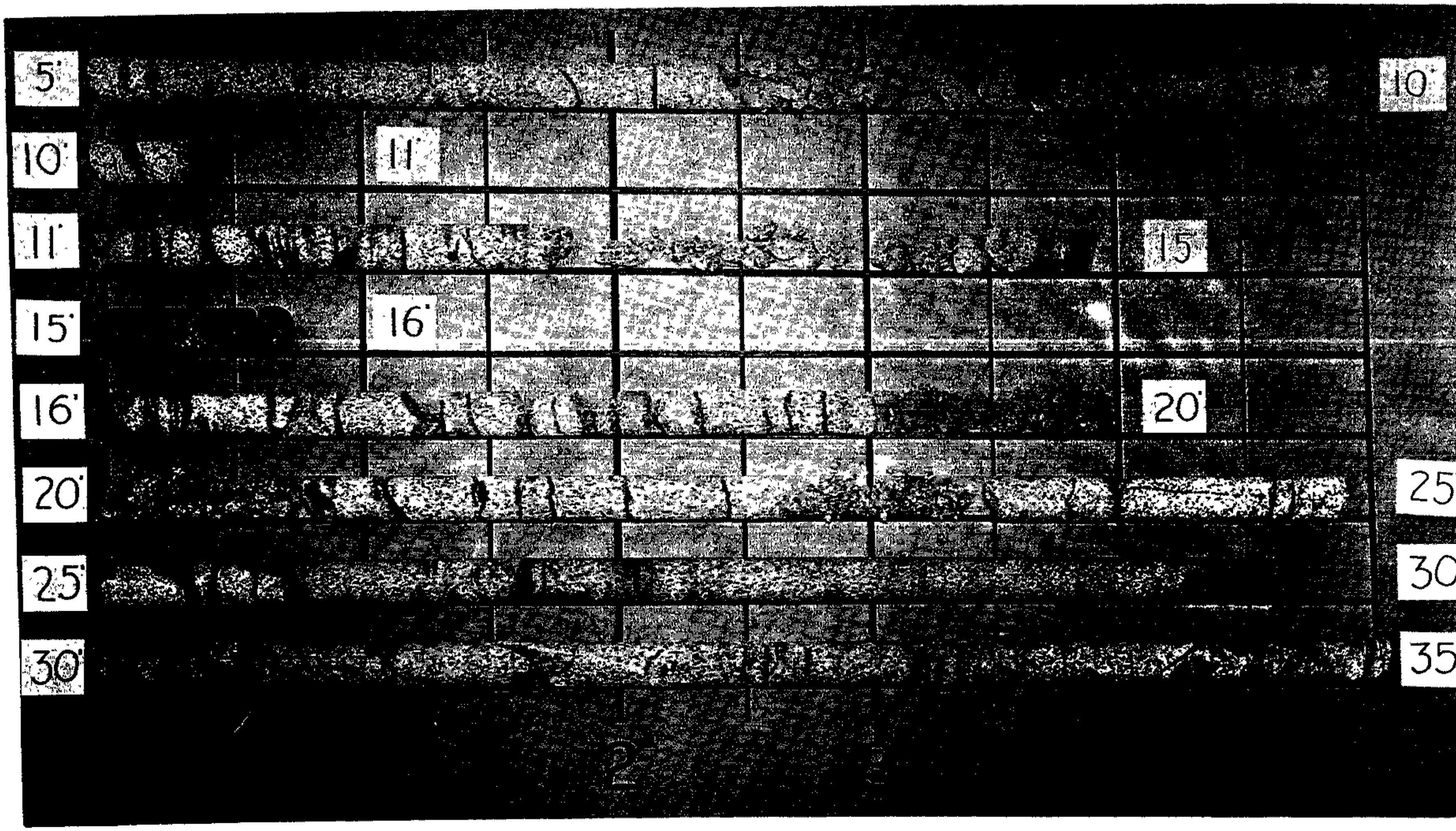
In comparing the present route and the low-level bridge route it should be noted that equal facilities are not being compared. They would not be equal as to length, grade alignment, and capacity. In fact, it is questionable if the two routes can be considered comparable. Only a two-lane road can be constructed along the existing route, whereas a four-lane road is feasible on the low level bridge line; also, alignment and grades would be superior on the bridge line.



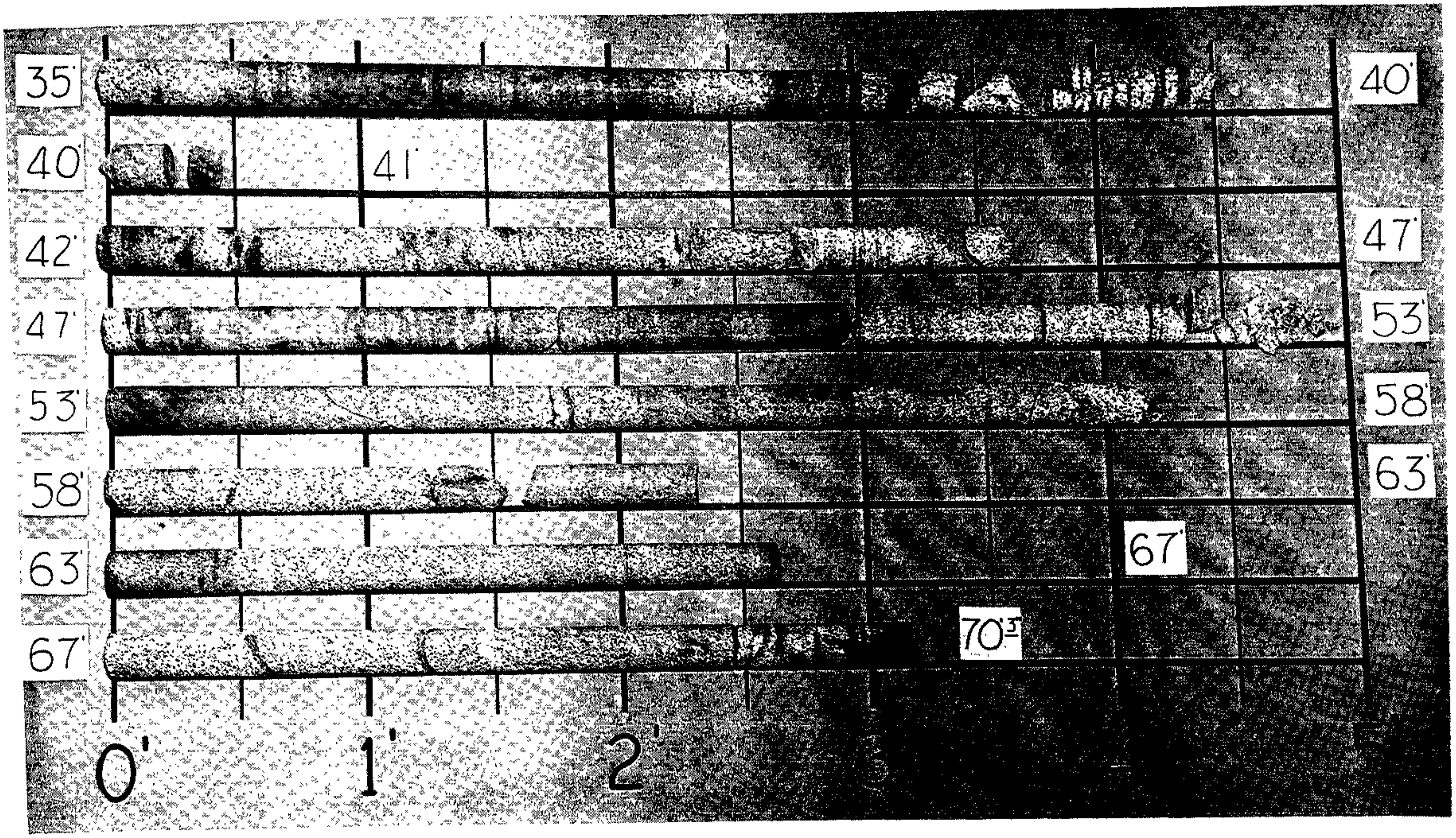
Emerald Bay Slide Investigation
Road III-ED-38-B
Boring R-1; 1' to 30'



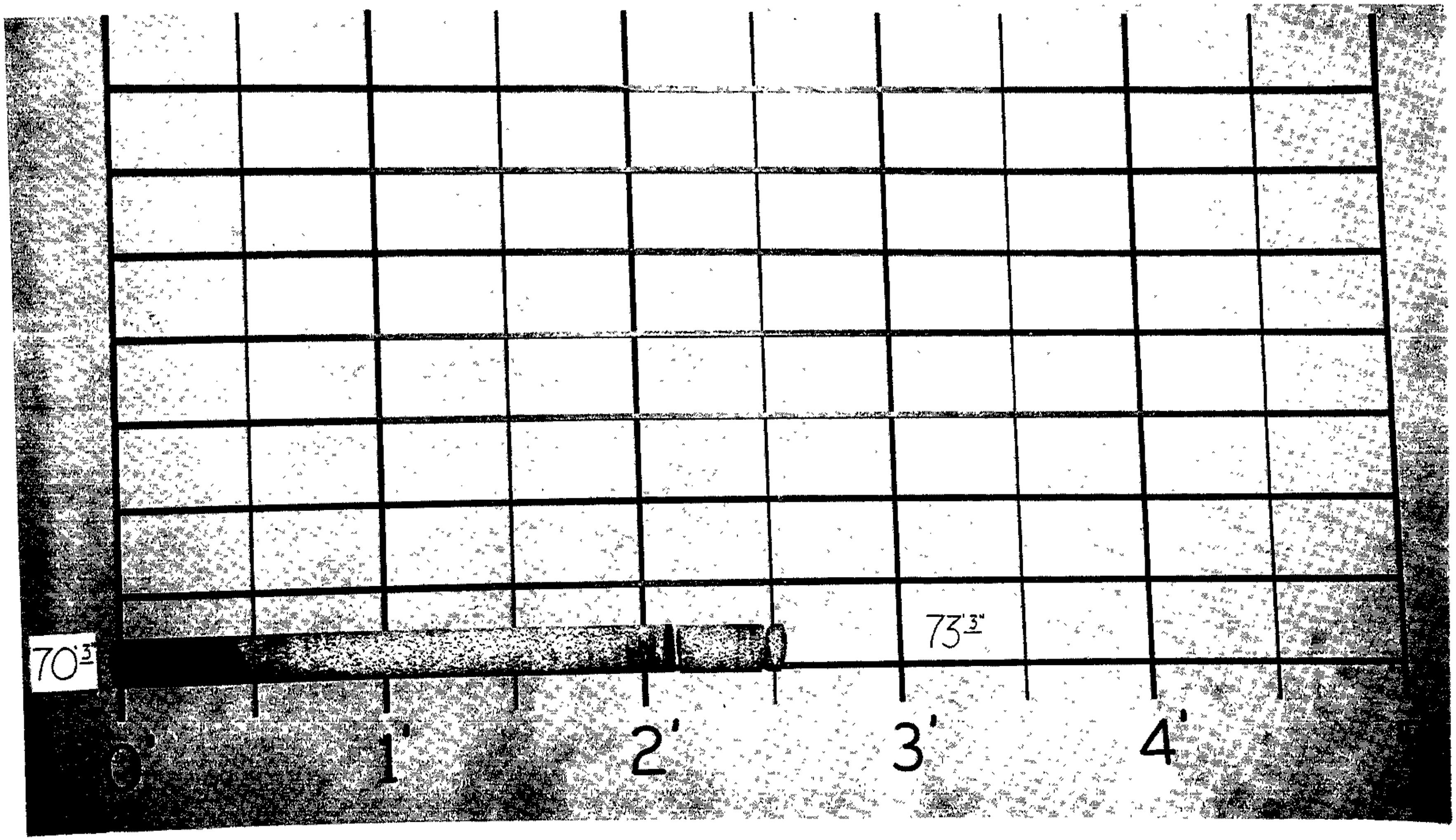
Emerald Bay Slide Investigation
Road III-ED-38-B
Boring R-2, 32' to 82'6"



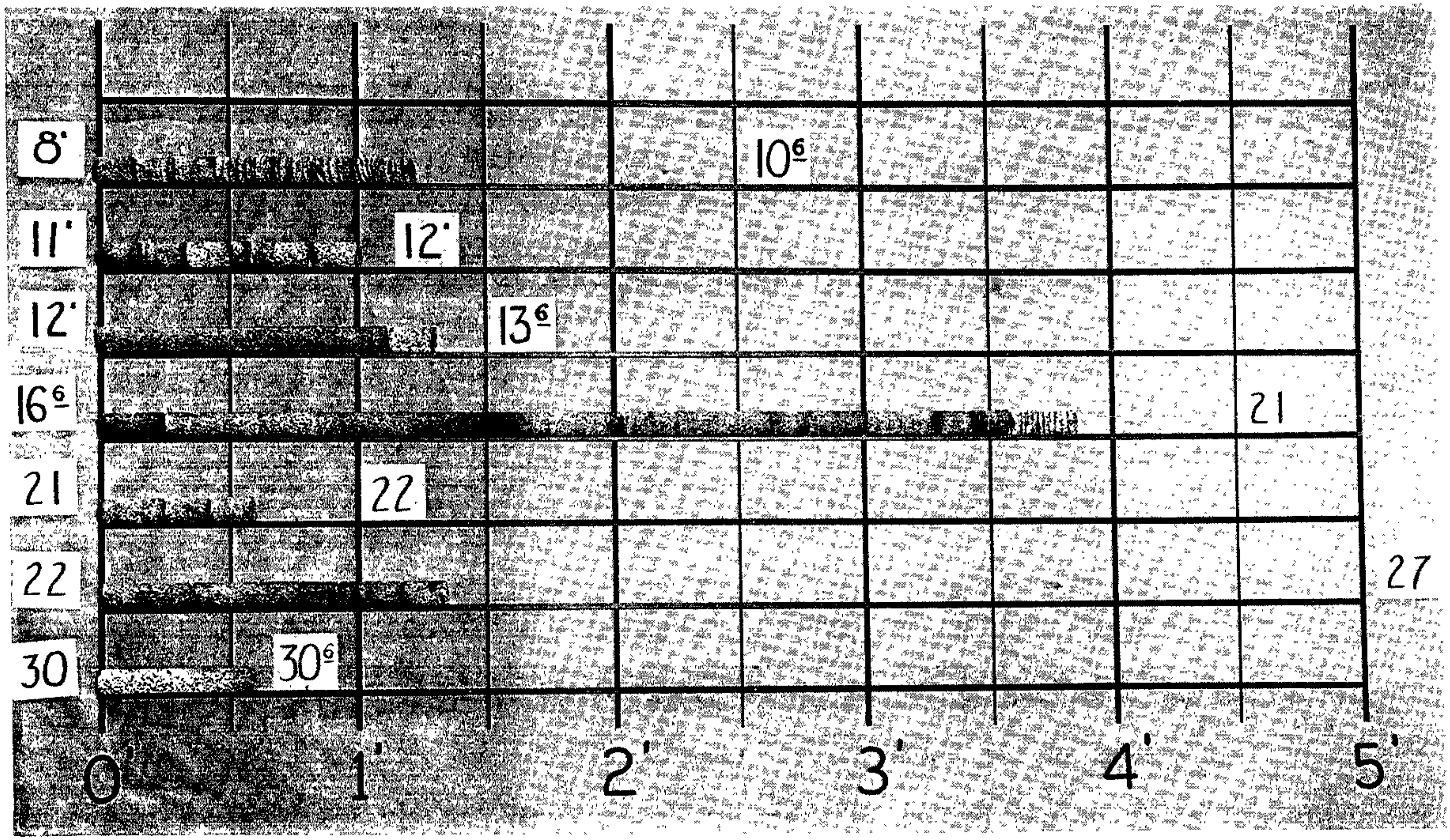
Emerald Bay Slide Investigation
Road III-ED-38-B
Boring R-3, 5' to 35'



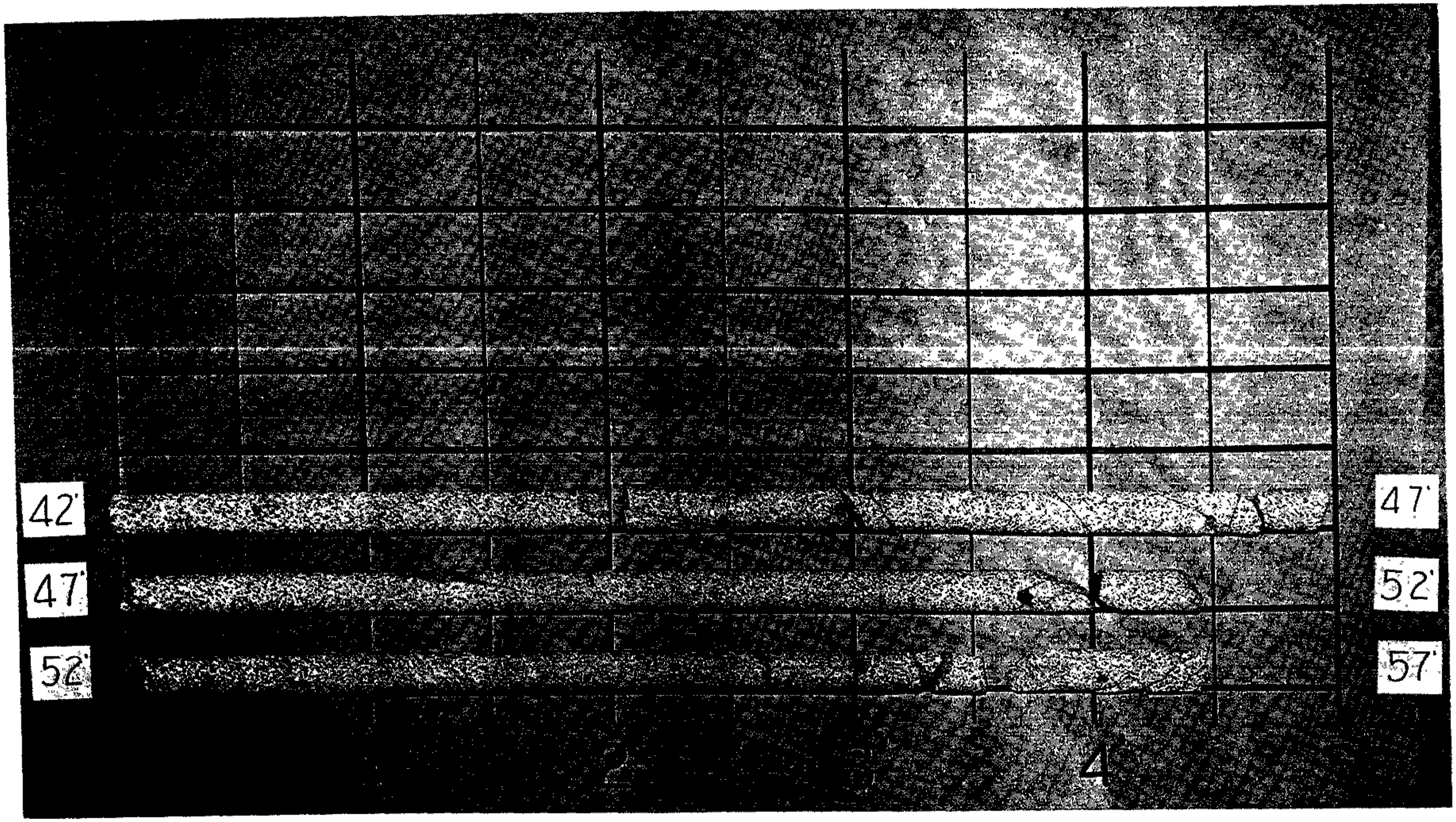
Emerald Bay Slide Investigation
Road III-ED-38-B
Boring R-3, 35' to 70'3"



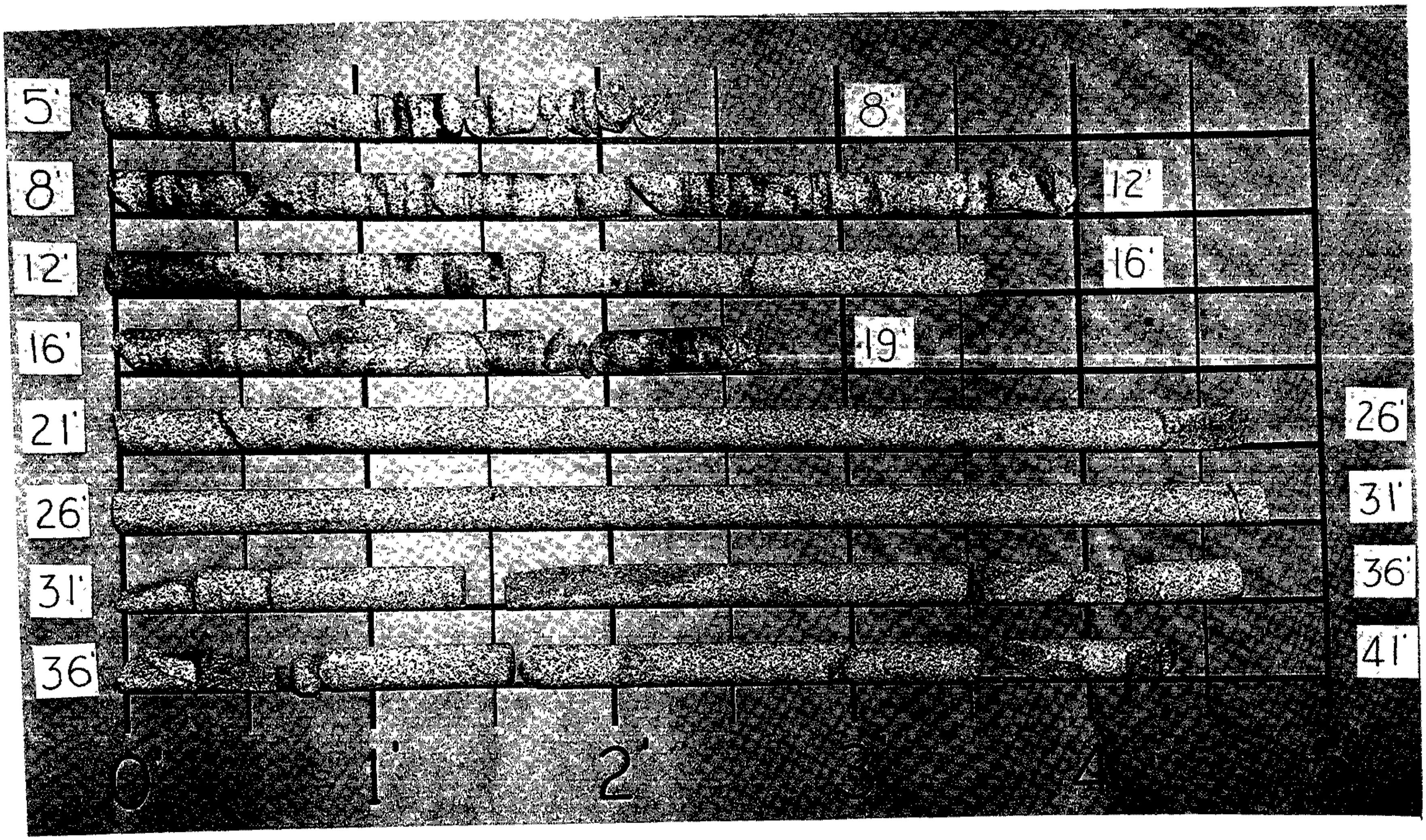
Emerald Bay Slide Investigation
Road III-ED-38-B
Boring R-3, 70'3" to 73'3"



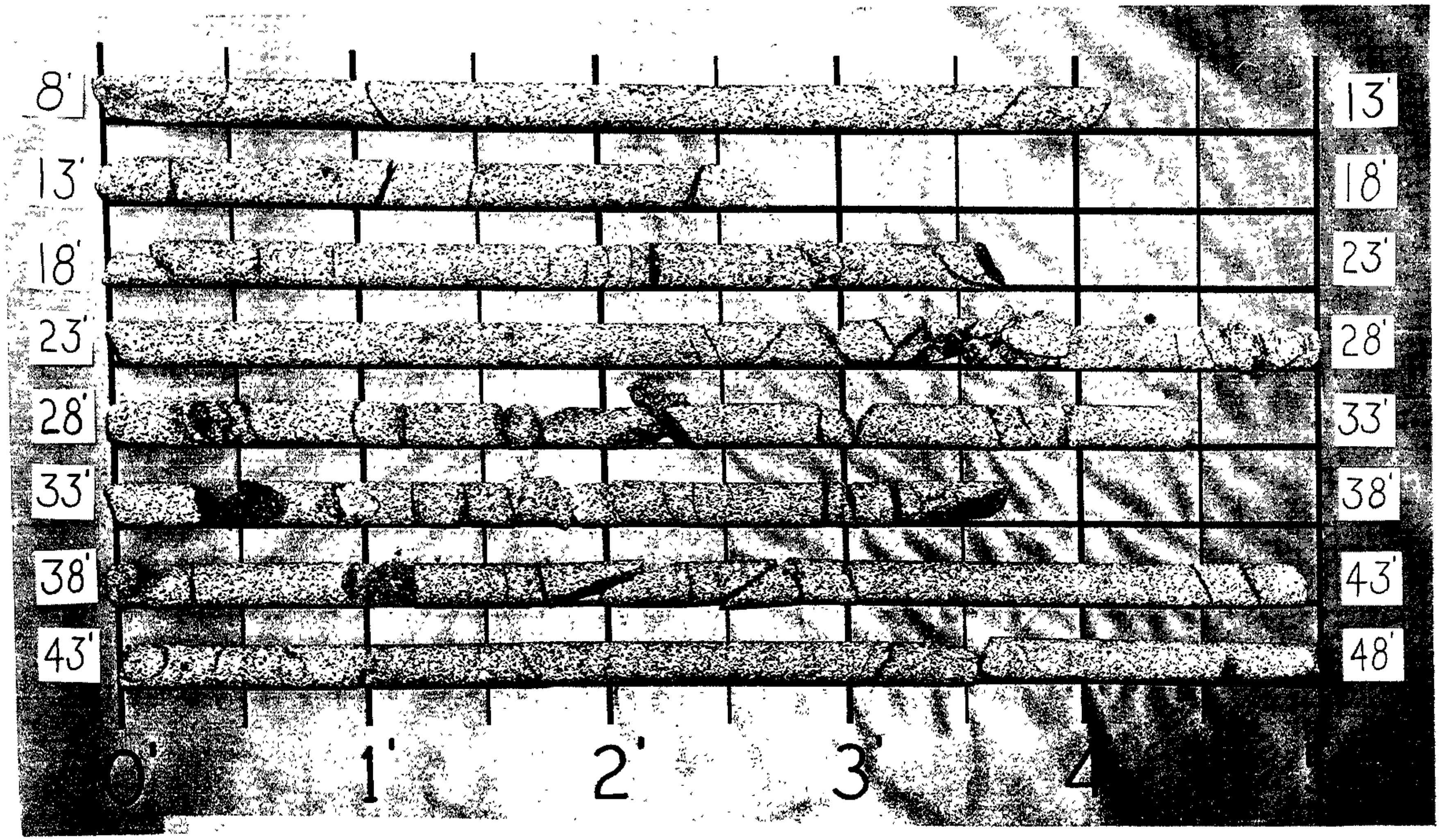
Emerald Bay Slide Investigation
Road III-ED-38-B
Boring R-4, 8'6" to 30'6"



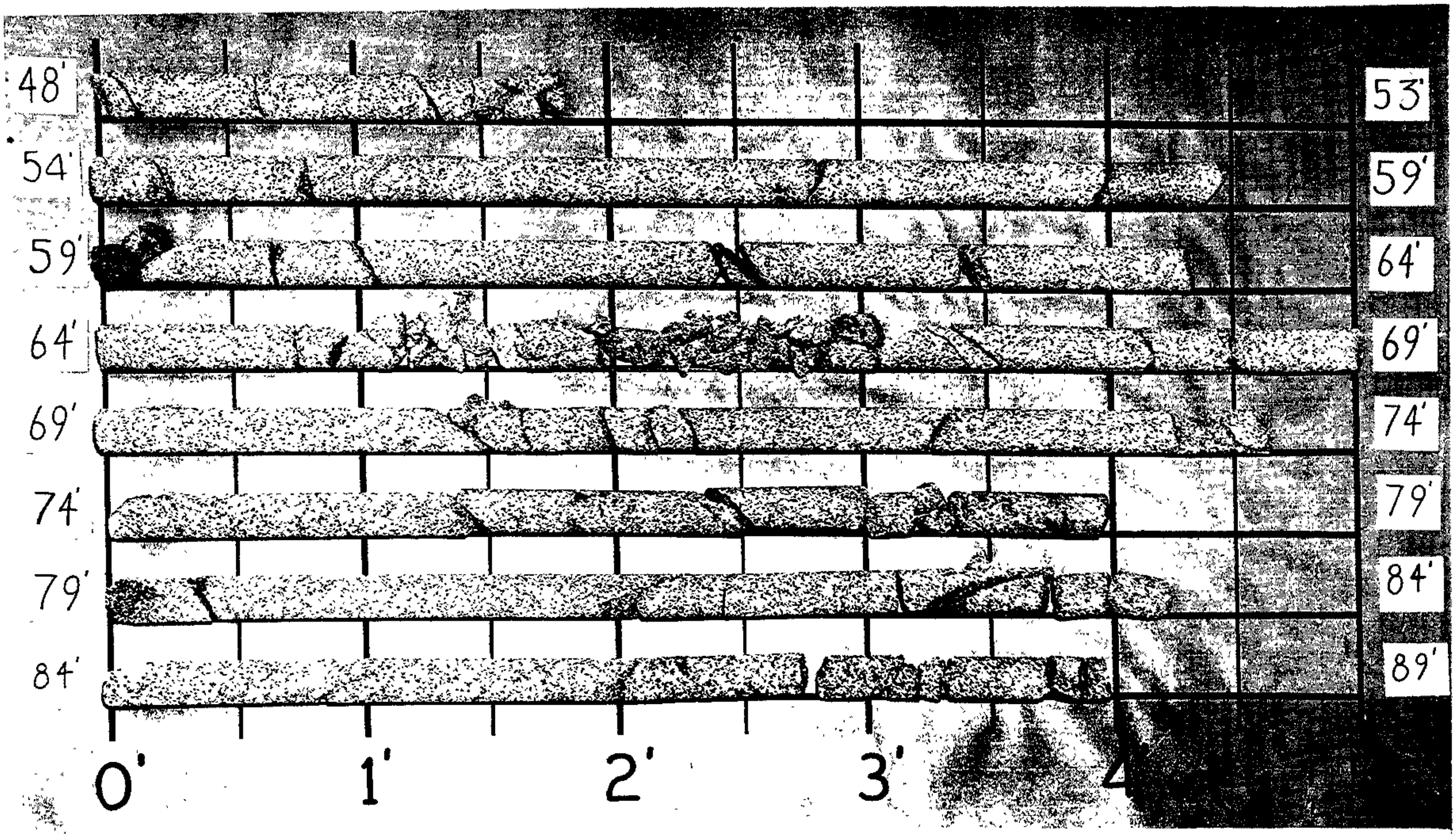
Emerald Bay Slide Investigation
Road III-ED-38-B
Boring R-5, 42' to 57'



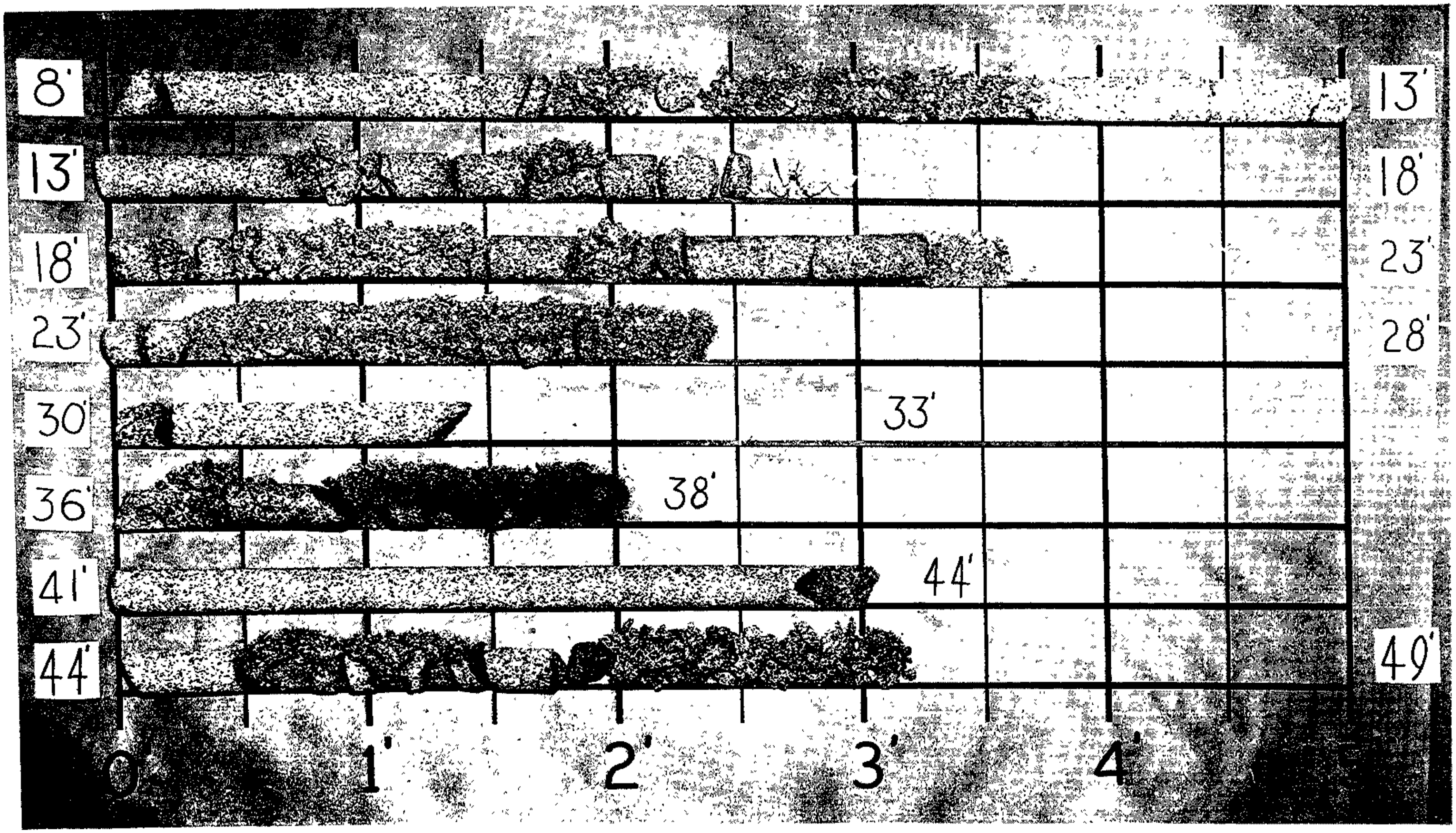
Emerald Bay Slide Investigation
Road III-ED-38-B
Boring R-5, 5' to 41'



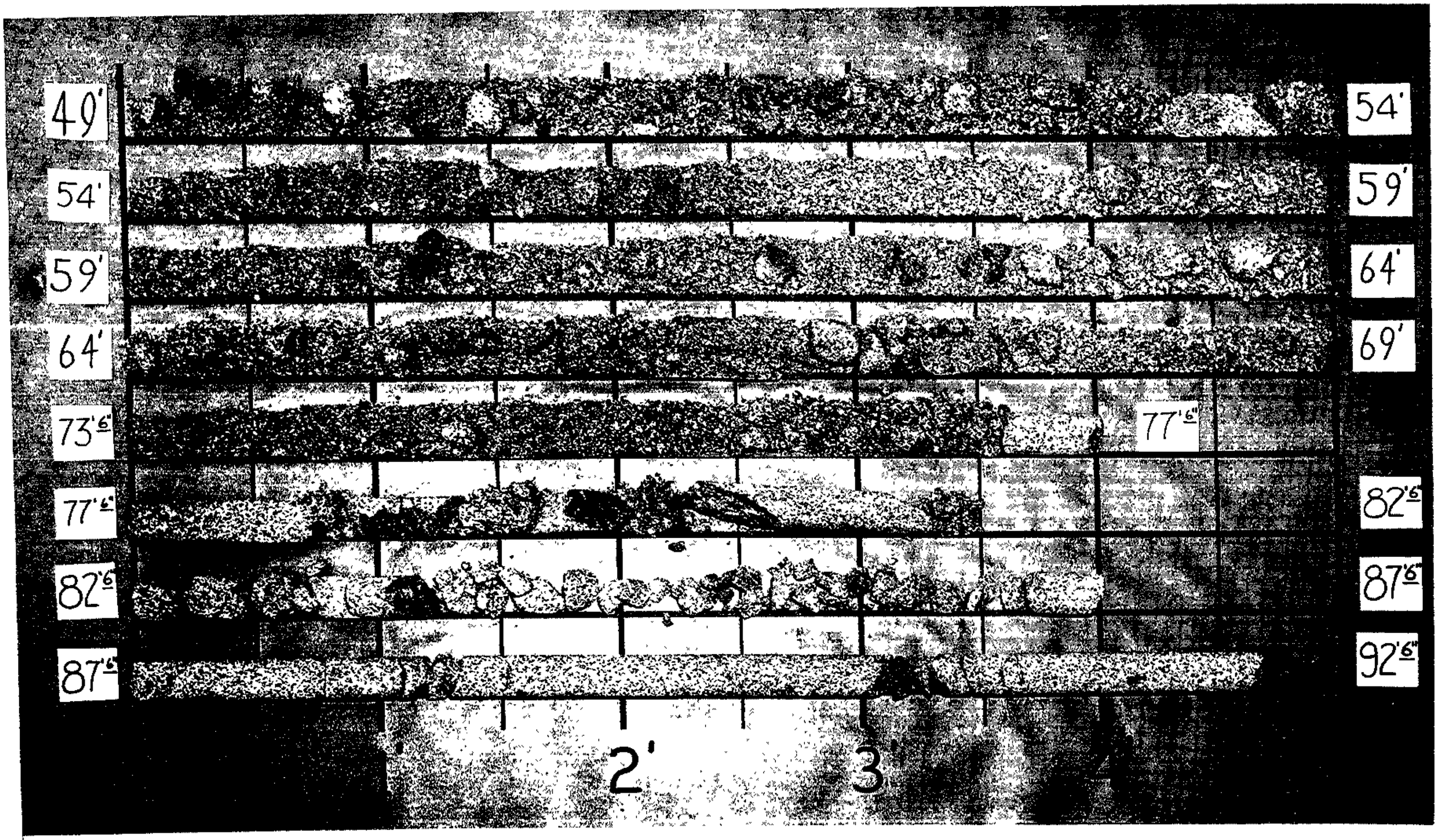
Emerald Bay Slide Investigation
Road III-ED-38-B
Boring R-9, 8' to 48'



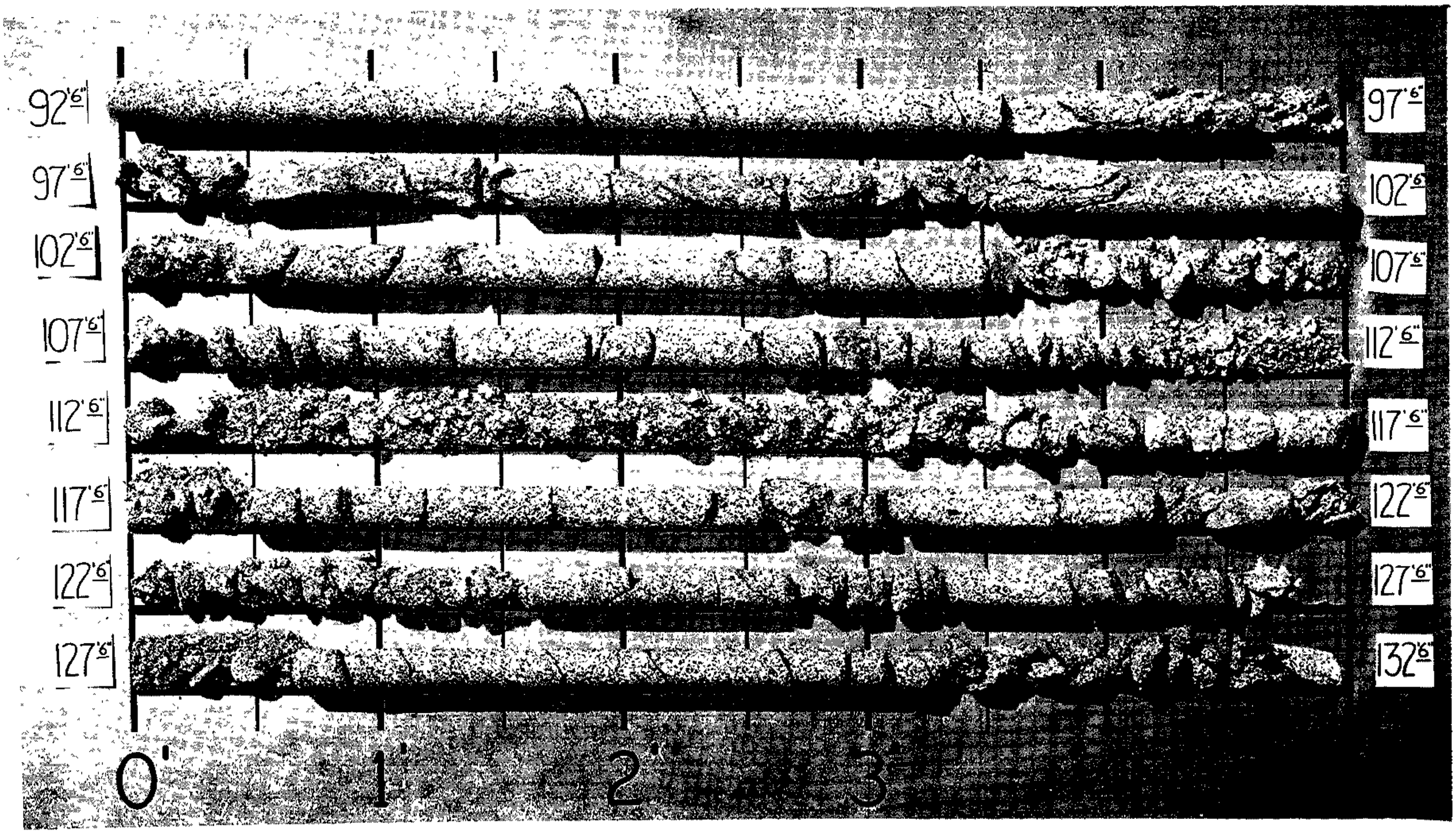
Emerald Bay Slide Investigation
Road III-ED-38-B
Boring R-9, 48' to 89'



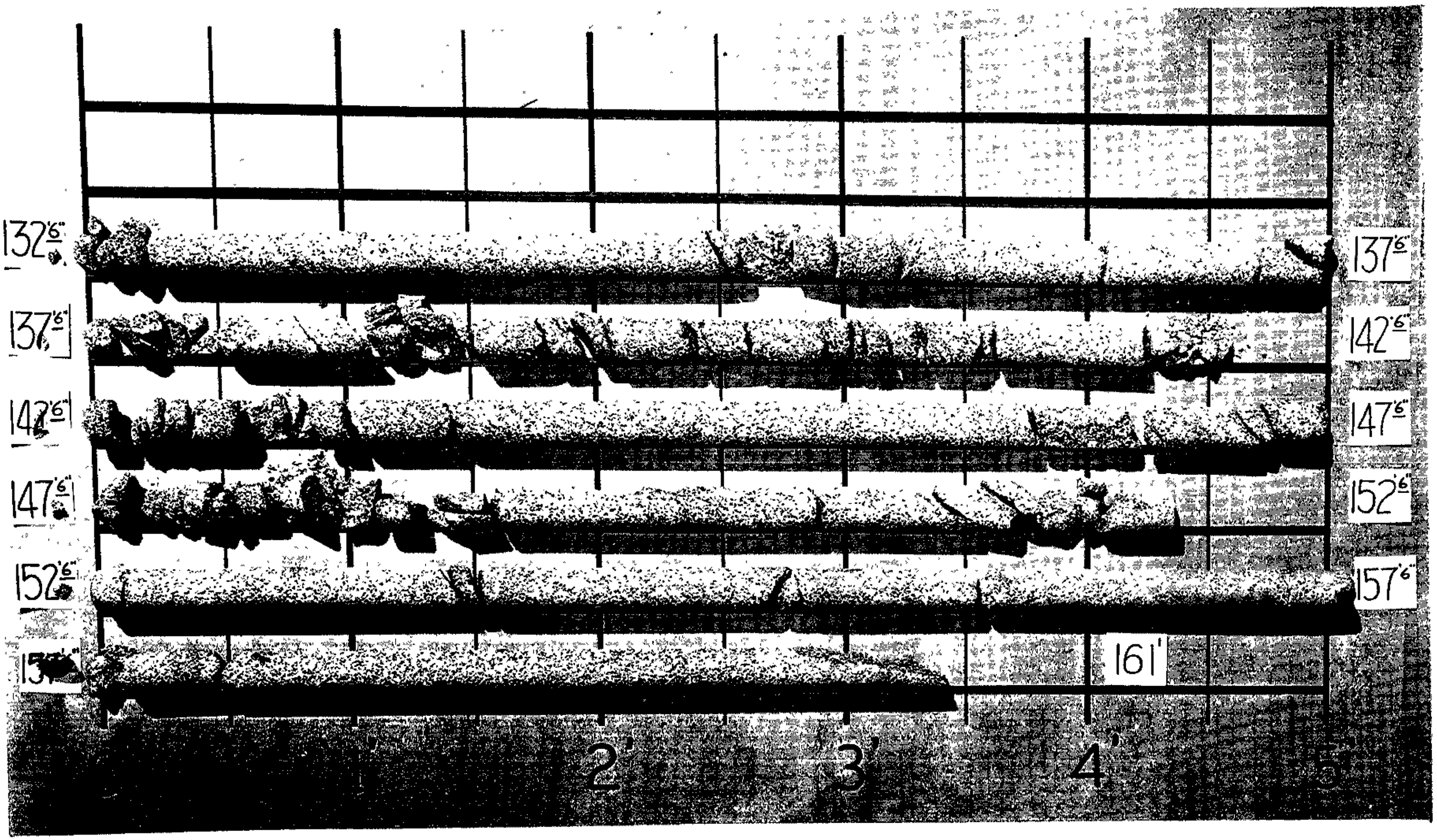
Emerald Bay Slide Investigation
Road III-ED-38-B
Boring R-10, 8' to 49'



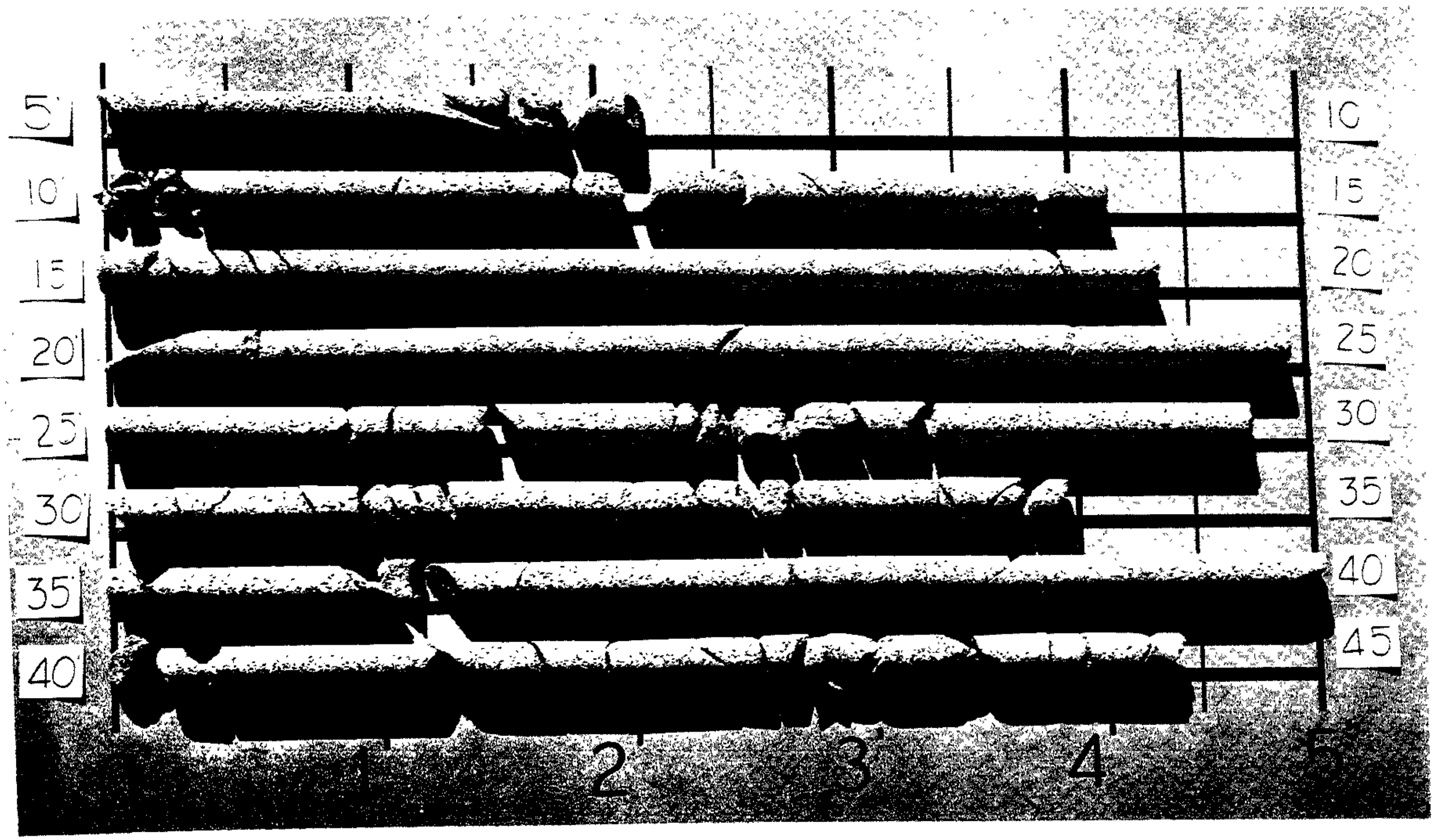
Emerald Bay Slide Investigation
Road III-ED-38-B
Boring R-10, 49' to 92'6"



Emerald Bay Slide Investigation
Road III-ED-38-B
Boring R-10, 92'6" to 132'6"

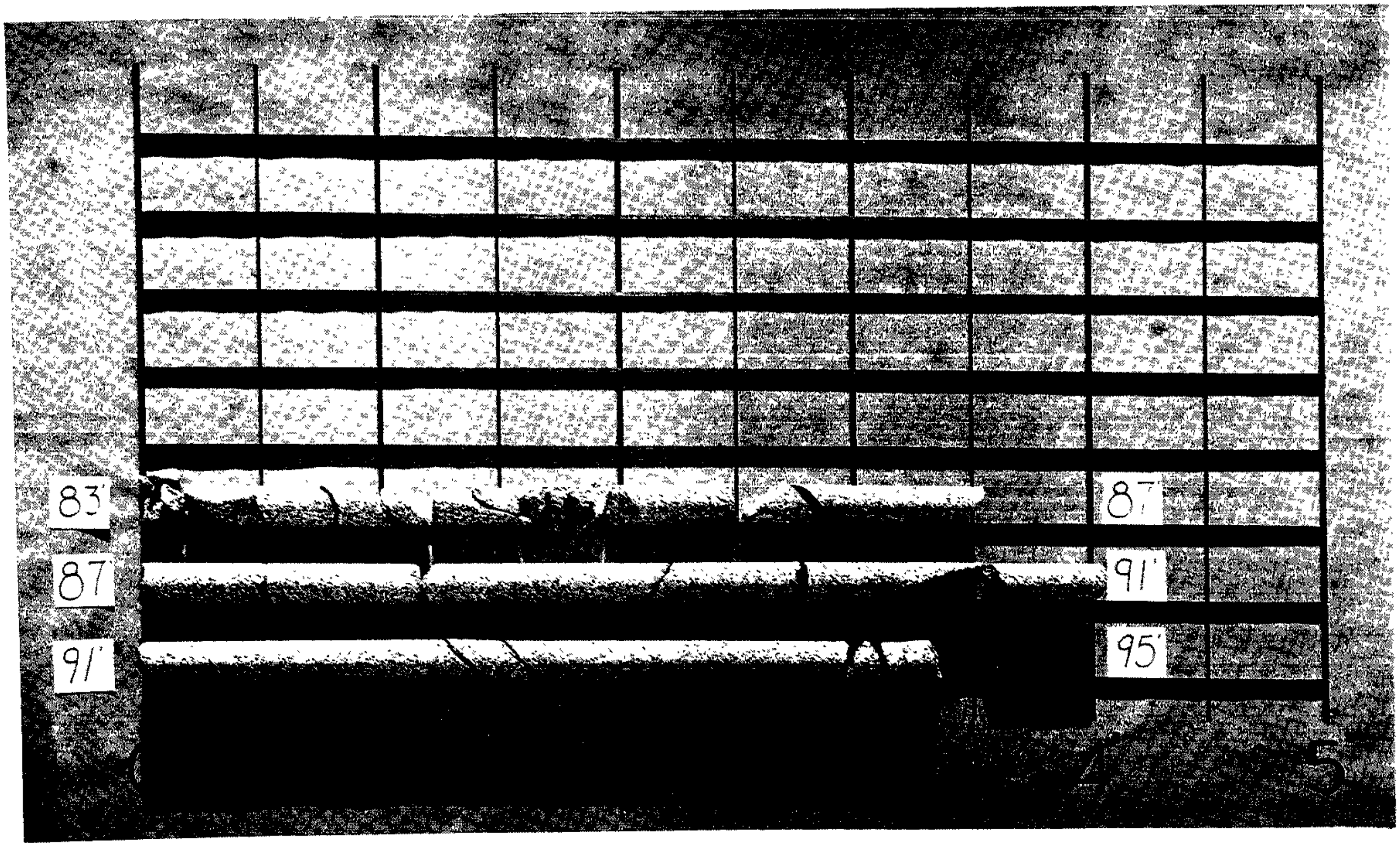


Emerald Bay Slide Investigation
Road III-ED-38-B
Boring R-10, 132'6" to 161'

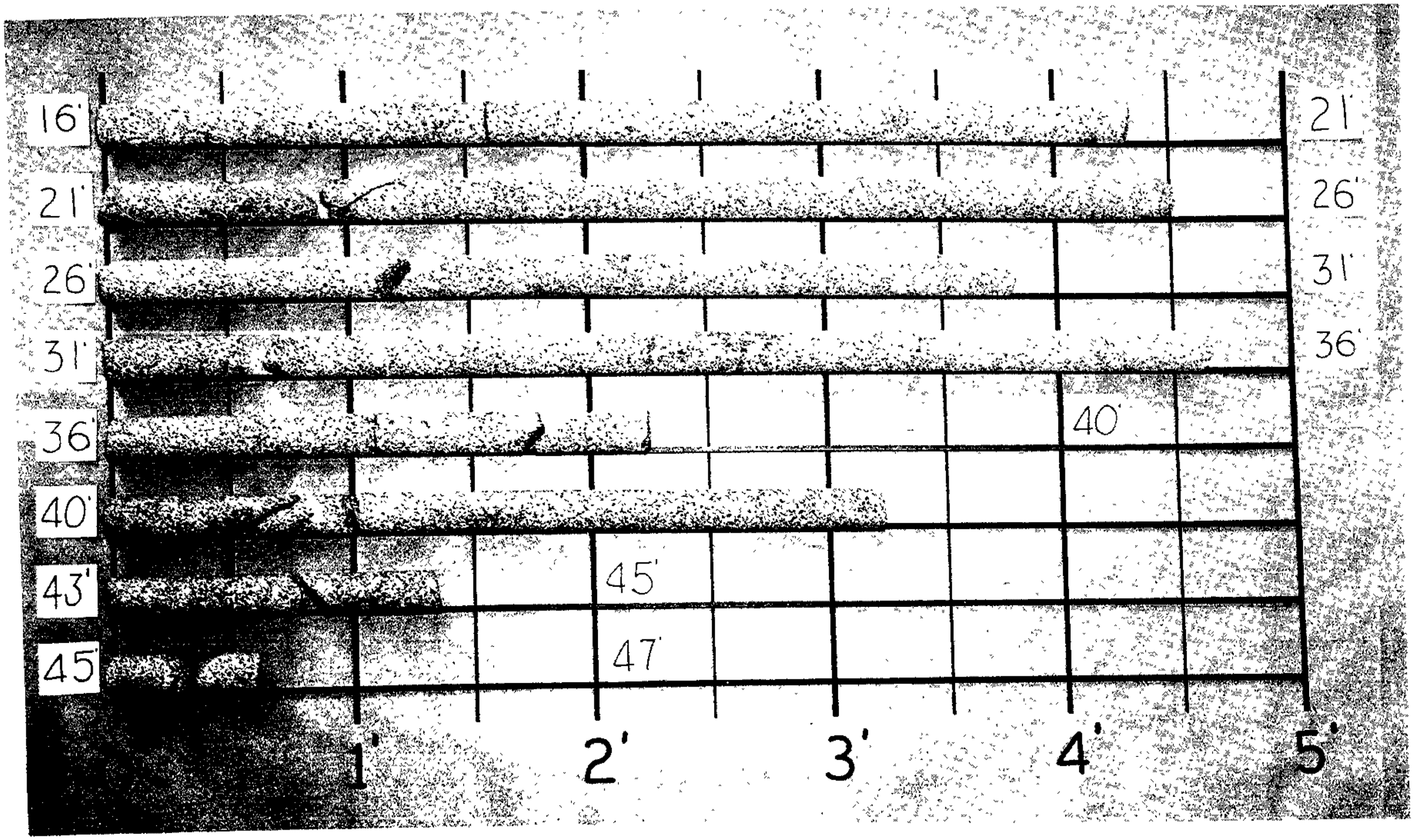


Emerald Bay Slide Investigation
Road III-ED-38-B
Boring R-11, 5' to 45'

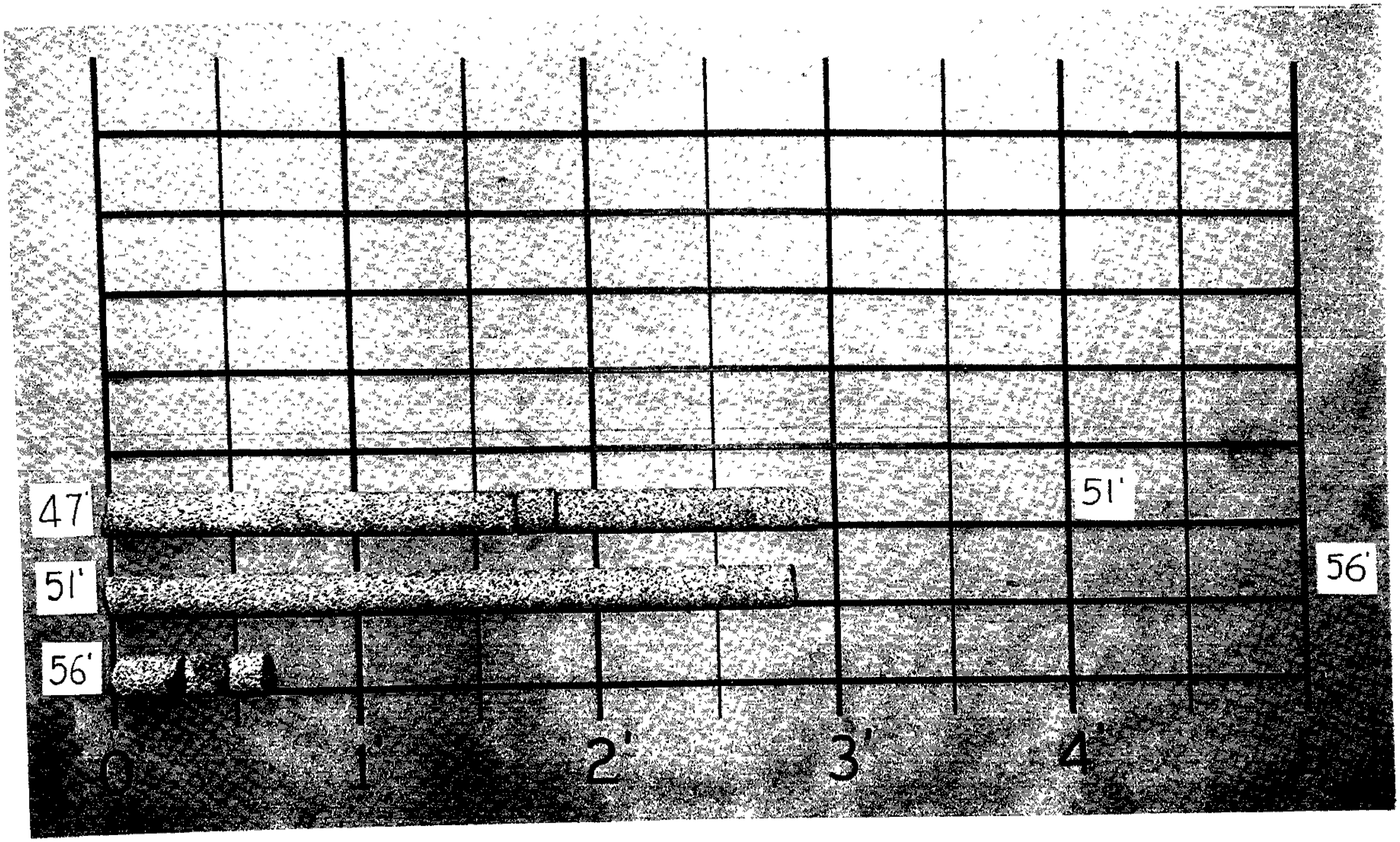
Emerald Bay Slide Investigation
Road III-ED-38-B
Boring R-11, 45' to 83'



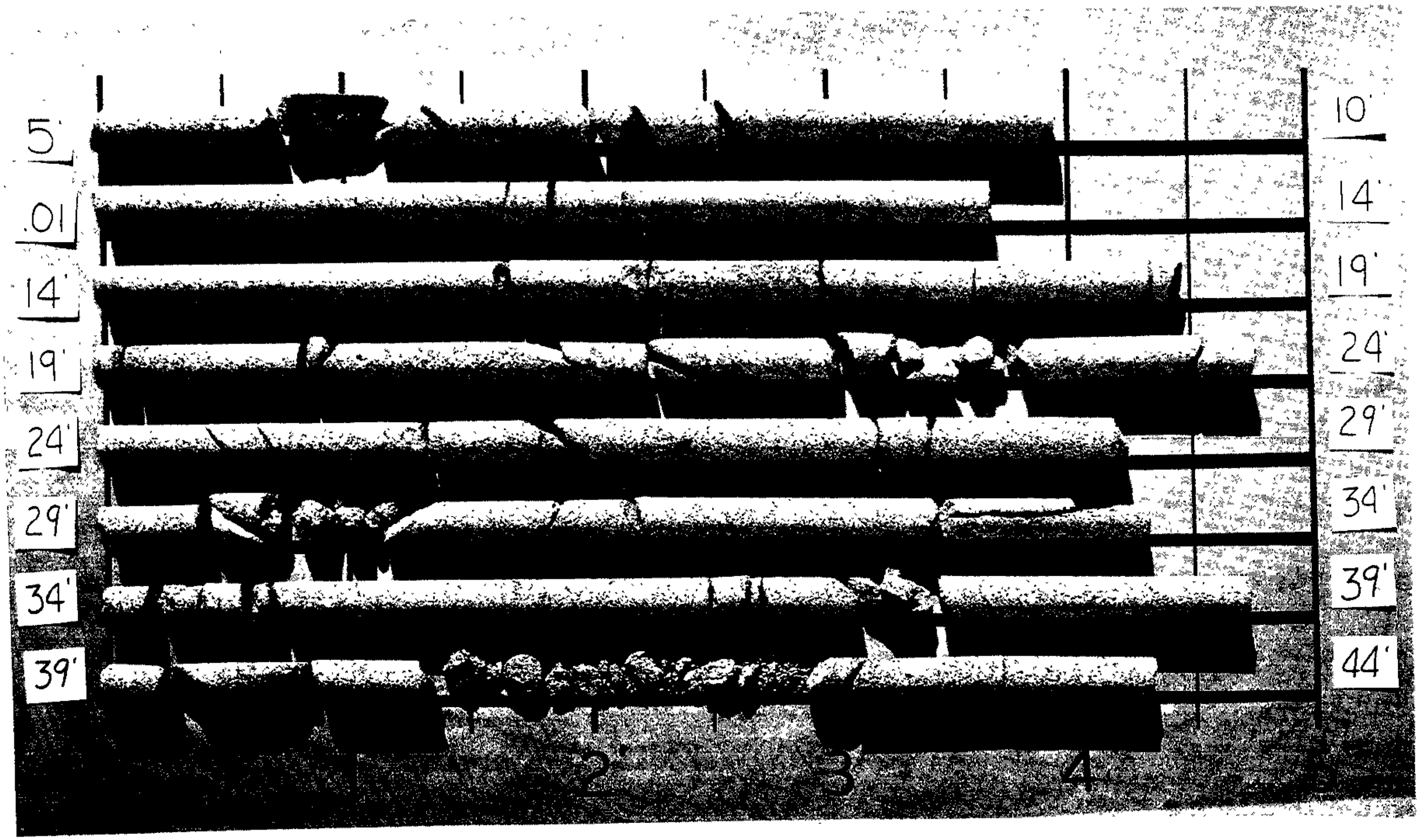
Emerald Bay Slide Investigation
Road III-ED-38-B
Boring R-11, 83' to 95'



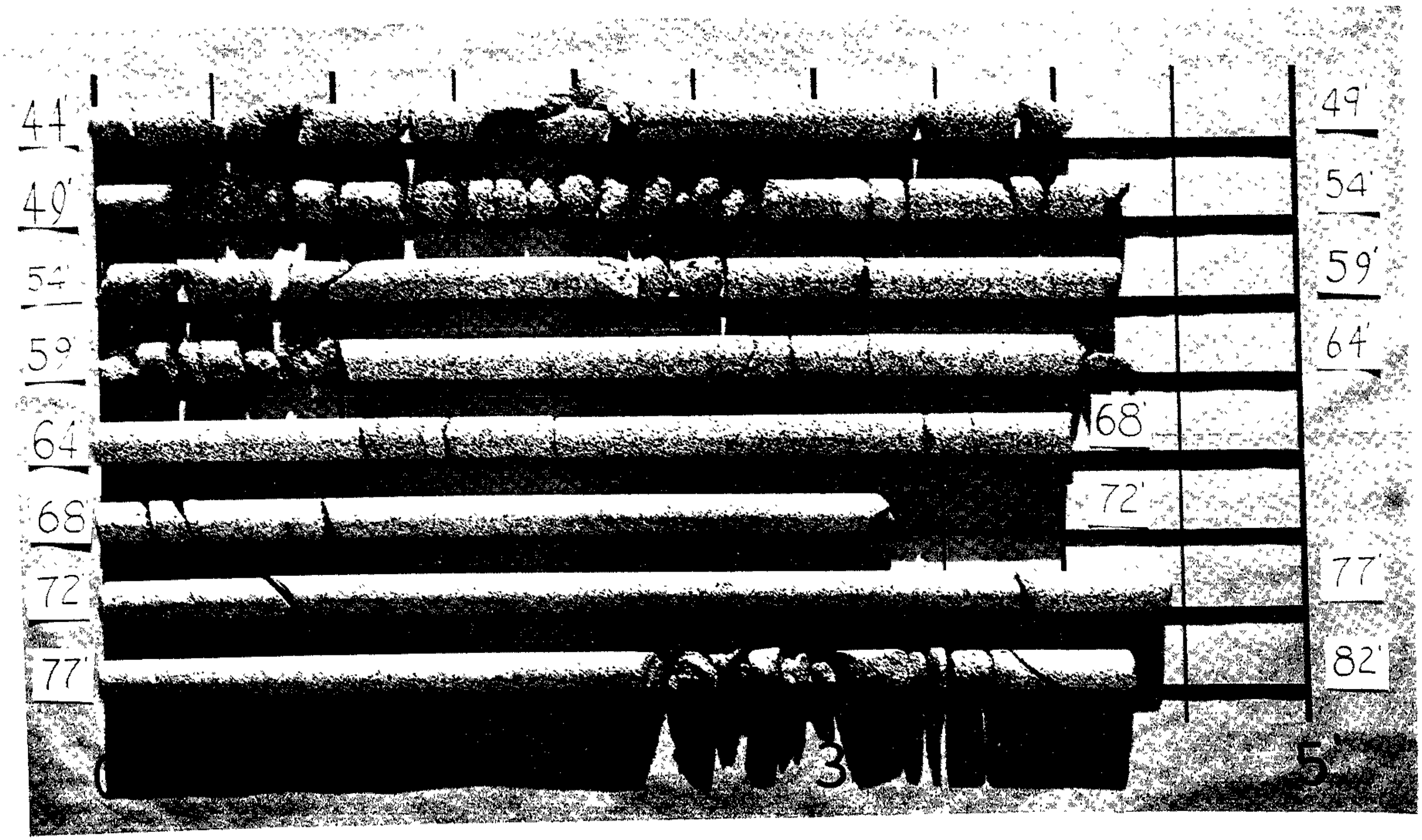
Emerald Bay Slide Investigation
Road III-ED-38-B
Boring R-12, 16' to 47'



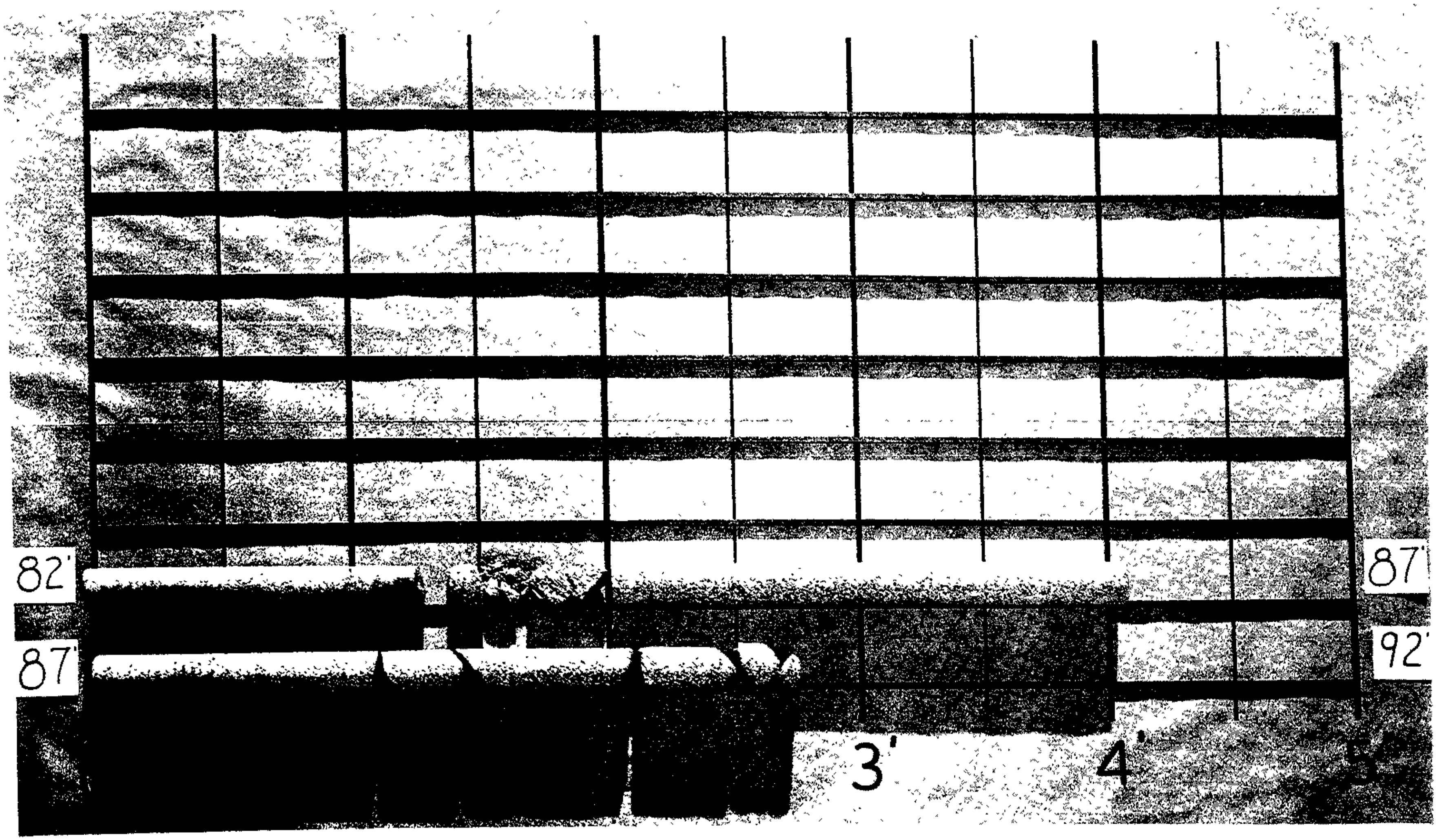
Emerald Bay Slide Investigation
Road III-ED-38-B
Boring R-12, 47' to 59'



Emerald Bay Slide Investigation
Road III-ED-38-B
Boring R-13, 5' to 44'



Emerald Bay Slide Investigation
Road III-ED-38-B
Boring R-13, 44' to 82'



Emerald Bay Slide Investigation
Road III-ED-38-B
Boring R-13, 82' to 92'

St. Louis, Mo.

July 28, 1957

Subject: Landslide, Emerald Bay, Lake Tahoe, California.

To: Mr. G.T. McCoy, State Highway Engineer

Att'n: Mr. F.N. Hveem, Materials and Research Engineer

From: Arthur B. Cleaves, Consulting Geologist

1.- INTRODUCTION

A field investigation was made of the landslide area at the head of Emerald Bay, on the west side of Lake Tahoe (T 13 N, R 17 E, Sec. 28) during the period July 23-24, 1957. The writer was accompanied in the field by Mr. T.W. Smith, Senior Materials and Research Engineer. Monday, July 22 and Thursday July 25 were spent chiefly in conferences with various officials in the Division of Highways, in Sacramento.

2.- PURPOSE

The principal purpose of this investigation was to ascertain the feasibility of a safe, all weather route through the slide area utilizing an open road; one protected by a snow shed; or by the construction of a 1,500 foot tunnel.

3.- A secondary purpose involved a reconnaissance of a "low-level" route close to the west shore of Lake Tahoe and including a bridge across the mouth of Emerald Bay.

4.- HISTORY & APPEARANCE

The available information indicates that the first slide movement took place in the late winter of 1953, and the second and larger movement occurred in the winter of 1956. Apparently there were no movement witnesses to these slide movements, hence the duration of each slide is a matter of conjecture. However, the appearance of the slide mass and the details of this investigation, suggest that the movement was of the avalanche type, possibly triggered by a snow-slide, and of short duration. It is definitely not of the typical slump type characterized by a semi-circular scarp at the head and an arc type slip plane beneath. There are no backward rotated, segmented units within the slide mass.

5.- DEBRIS MANTLE & MOVEMENT

Because of the type of slide movement and these studies it is considered doubtful if the debris mantle in the area above the present road has a thickness of over fifty feet. Some 200,000 cubic yards of debris are reported to have been removed in order to open up the road after the 1956 slide. This operation necessitated the creation of many "dozer" benches over the upper slide surface and these mask to a considerable degree the detailed directional courses of the debris "streams".

6.- Below the highway the debris "cones" are almost completely veneered by the 200,000 cubic yards of slide material cleared from the area above the highway. Nevertheless, it is quite clear that in its progress downslope the tumbling and sliding debris split, north and south, of a resistant granite mass which may be observed as island-like masses just above and just below the highway. These rock "islands" are severely shattered and superficially, at least, disturbed, but nevertheless sufficiently solid to have split the avalanche and probably prevent a section of the road from being carried away.

7.- GEOLOGY

The bedrock in place in the area of, and as debris within the slide mass consists of a medium-grained granite. This granite has been severely affected by tectonic (mountain-building) movements related to the Sierra Nevada Mountains origin. The rock at the head of Emerald Bay is characterized by very severe faulting and jointing. Accompanying the fracturing and slipping of the granite, "crush zones" developed between many of the joints and probably also between some of the faults. Within these crushed zones weathering has facilitated the decomposition of the feldspar minerals in the granite so that it may be easily excavated with a pick and shovel. The entire nose of the mountain spur immediately south of the slide area is a large scale example of such decomposition. Within this spur the planes of faulting and the master joint system may be observed and measured. Just north of the immediate slide area no such crushed and decomposed zones exist. Consequently, in the slide area proper an intermediate condition exists where there are localized zones of solid rock and crushed and decomposed rock.

8.- The geometrical attitude of the faults and joints is as follows: (these readings are not corrected for magnetic declination).

	Faults - average strike	Faults - dip	Joints - average strike	Joints - dip
Northwest Margin Slide above Road	N59°W	42°NE	N68°E	71°SE
South Margin Slide below Road	N55°W	34°NE	N68°E	Steep
South Margin Slide above road in decomposed granite	N45°W	43°NE	N75°E	70°SE

These areas were not disturbed by the slide movement. The strike and dip of the joints are essentially constant, and the strike and dip of the faults is consistent, bearing in mind that these fault surfaces are gently undulating. The fault spacing varies from 0.15 feet to about 4.0 feet and the joint spacing falls into the same range. Within the crush zones between the joints the lines of strain intersect the joints at an angle of about 70°.

Where fault planes show within the area of the disturbed debris of the slide some fit into the normal but others are obviously on granite blocks that have rotated and tilted. In the solid granite north of the slide area the normal fracture and fault pattern is observed but in addition intersecting faults produce a wedge pattern.

9.- These data demonstrate beyond any question of doubt that the slide debris rests on strongly faulted and fractured granite containing crush zones. Consequently, any tunnel operation or rock backwall for a snow shed will be in "blocky and seamy" rock with crush zones equivalent to "running" ground.

10.- TUNNEL CONSTRUCTION

One solution proposes a tunnel about 1,500 feet long, on a somewhat different alignment curving back under the slope of the slide with a maximum cover of about 150 feet. It is my opinion that this would place the tunnel beneath all active elements in the slide and into undisturbed ground. However, such a tunnel would not be in unfractured, unfaulted, or undecomposed granite. Indications are that from 10% to 20% of the tunnel, and particularly the south portal, will be in crushed granite and that excavation methods in such ground would be essentially those required in "earth tunneling". The balance of 80% to 90% of the tunnel would be in "blocky and seamy" ground. Obviously the cost of tunneling under such conditions is more expensive than boring through solid rock. Nevertheless, a lined tunnel here would, in my opinion, provide a road section free from damage by slides such as have been experienced.

11.- SNOW SHED CONSTRUCTION

The successful construction of a concrete show shed, safe from destruction in whole or in part by future snow slides or landslides is problematical at this writing. Such a solution depends on secure anchorage to rock beneath and on the backwall side of the structure. Whereas the slide caused no apparent failure below, or of the highway itself, suggesting good foundation conditions, one cannot vouch for the backwall. The slide mass appears to be free debris close above road level in several places. If such is the case future slide movements could build up lateral pressures sufficient to "take out" sections of the snow shed. If undisturbed rock can be found for rock-bolting on the backwall, then a snow shed, with a debris apron on top to absorb shock and deflect snow and rolling rock, can be considered feasible.

12.- ADDITIONAL EXPLORATION

Insofar as further exploration is concerned none is essential for the tunnel, but on the other hand is most desirable for determining the feasibility and safety of a snow shed. Consequently, several bore-holes are recommended. At the highway level three angle holes drilled at about 20° from the horizontal, and about N45°E (uncorrected for declination) directionally appear desirable. This angle and direction will insure exploration across both the fault planes and the master joint pattern with its localized crush zones. As a result they should reveal the presence or absence of rock suitable for rock-bolting and support for a snow and slide shed. It would also be desirable to investigate the thickness of the slide debris mantle above the highway for the purpose of estimating the volume of material that may be removed and to determine its thickness above the proposed tunnel line. The location and details relative to most of these borings have been discussed with Mr. Smith in the field.

13.- LOW-LEVEL HIGHWAY RELOCATION

The proposed line of a highway location close to the west shore of Lake Tahoe with a bridge across the mouth of Emerald Bay was also examined. Whereas this investigation was of a brief reconnaissance type enough information was gained to indicate that a two lane route and a bridge are feasible. The "tight" spots where the most delicate alignment is involved occur on the steep slopes adjacent to cliff faces in the 1,500 feet to 2,500 feet northwest of the flat point of land on the north side of Emerald Bay. However, there is a narrow "bench" just underwater at the lake margin and the necessary fills could be "toed in" on it. In addition, the apparent soundness of the rock in the "cliff" faces suggests that any program of rock-bolting in the rock cut areas would be successful.

The water appears to be relatively shallow across the mouth of Emerald Bay and it is believed sound bearing for the bridge piers and abutments can be found.

The line south of the mouth of Emerald Bay appears definitely feasible and does not seem to offer any especial problems. In general the low-level highway route offers a much better alignment than the present route.

Signed:

Arthur B. Cleaves
Consulting Geologist

Copies (4)

Service Agreement: No. MR-106

St. Louis, Missouri.
October 3, 1957.

Subject: Landslide, Emerald Bay,
Lake Tahoe, California.

To: Mr. G.T. McCoy, State Highway Engineer

Att'n: Mr. F.N. Hveem, Materials & Research Engineer

From: Arthur B. Cleaves, Consulting Geologist

1.- INTRODUCTION

This report is the second made of the landslide area at the head of Emerald Bay, on the west side of Lake Tahoe (T 13 N, R 17 E, Sec.28). A preliminary report was made as the result of an investigation conducted during the period July 23-24, 1957. Since that time certain core borings have been completed and a second field examination has been made, on September 23-24, 1957.

On this second field investigation the writer was accompanied by Mr. A.W. Root, Supervising Materials and Research Engineer, Mr. T.W. Smith, Senior Materials and Research Engineer, and Dr. Parker D. Trask, a consulting geologist from the University of California

At the risk of being redundant several of the following paragraphs are more or less identical with the preliminary report. This is done so that the reader will not have to refer constantly to the earlier report.

2.- PURPOSE

The purpose of these investigations has been to ascertain the feasibility of a safe, all weather route through the slide area utilizing either an open road; one protected by a snow shed; or by the construction of a 1,100 to 1,500 foot tunnel. A secondary purpose involved the practicability of a "low-level" route close to the west shore of Lake Tahoe, and including a bridge across the mouth of Emerald Bay.

3.- HISTORY AND APPEARANCE

The first recorded movement of this slide took place late in the winter of 1953, and the second, and major movement occurred in the winter of 1956. Because there are no known witnesses to these slide movements the duration of each slide is a matter of conjecture. Nevertheless, the general appearance of the slide mass and the details of these investigations suggest that at least the major movement was of the avalanche type. It is definitely NOT the typical slump type of slide characterized by a semi-circular scarp at the head and an arc type slip-plane beneath. The movement was a sliding and tumbling one with no backward rotated, segmented units within the slide mass.

4.- DEBRIS MANTLE AND MOVEMENT

Because of the type of slide movements and these investigations it is considered doubtful if the debris mantle in the area above the present roadway has a thickness of over fifty feet. Because of the variabilities in this thickness it is thought that an overall average will be between fifteen and twenty-five feet. Approximately 200,000 cubic yards of debris are reported to have been removed in order to open the road after the 1956 slide. This operation necessitated the creation of many "dozer" benches over the upper slide surface. The majority of these are sloped northward and today mask to a considerable degree the detailed directional courses of the debris "streams".

5.- Below the highway the debris "cones" are largely veneered by the 200,000 cubic yards of slide material cleared from the area above the road. Nevertheless, it is quite obvious that in its progress downslope the tumbling and sliding debris split, north and south of a "resistant" granite mass which may be observed as island-like masses just above and just below the highway. These rock "islands" are severely shattered and superficially at least, disturbed, but nevertheless sufficiently firm to have split the avalanche and probably prevent a section of the road from having been carried away. A future slide movement might cause the failure and destruction of these "island" masses.

6.- GEOLOGY

The bedrock in place in the area of, and as debris within the slide mass consists of a medium-grained granite. This granite has been severely affected by tectonic (mountain building) movements related to the formation of the Lake Tahoe graben and the Sierra-Nevada Mountains origin.

7.- The rock at the head of Emerald Bay is characterized by very severe faulting and jointing. Accompanying the fracturing and slipping of the granite, "crush" zones developed between many of the joints and probably also between some of the faults. Within these crushed zones weathering has facilitated the decomposition of the feldspar minerals in the granite so that in many places it may easily be excavated with a pick and shovel. The entire nose of the mountain spur immediately south of the slide area is a large scale example of such decomposition. Within this spur the planes of faulting and the master joint system may be observed and measured. Just north of the immediate slide area no such crushed and decomposed zones exist except in a very minor degree. Consequently, in the slide area proper an intermediate condition exists where there are localized zones of solid rock, and crushed and decomposed rock.

8.- The faults in the Emerald Bay slide area are undulating in character and vary in strike from N 45° W to N 59°W (uncorrected for magnetic declination). The dip of these faults varies from 34°NE to 43°NE. Within the slide area proper the planes of faulting pass beneath the "island-like" granite masses that split the avalanche of debris, hence one reason to doubt their permanent stability and resistance against future movements.

9.- The principal joints show a strike varying from N 68°E to N 75°E (uncorrected for magnetic declination) and a dip of 70° to 71° SE.

10.- The measurements of the fault surfaces and the joints in the "island masses" within the slide area do not agree with the average measurements taken outside of the disturbed area, hence reason to believe these masses have been crushed and moved to some degree, by the slide forces.

11.- These data demonstrate beyond any question of doubt that the slide debris rests on strongly faulted and fractured granite containing crush zones. Consequently, any tunnel operation, or rock backwall and footings for a snow-shed will be in "blocky and seamy" rock with crush zones equivalent to (possibly) "running" ground.

12.- SNOW SHED CONSTRUCTION

The feasibility of constructing a snow shed in the slide area with any assurance of security is given less than a 50 - 50 chance of permanency. For reasons discussed below it is not recommended.

13.- The only type of snow shed considered after the original investigation was more or less the Swiss type. This involves a reinforced concrete structure, anchored to bedrock both through the footings and along the backwall. The roof is a reinforced, prestressed concrete slab inclined about 15° downslope. It would be mantled with soil overburden of a minimum thickness of about 5 feet. In addition, because of the roadway width, a row of center supportswould be necessary. In addition the backwall of the shed would have to be bolted to rock and the rock itself would have to be rock-bolted because of its faulted and fractured condition. Considerable excavation into the rock would be required and this to a depth insuring firm rock beneath the mantle of slide debris.. In addition, it is believed that the slide debris above the road would have to be cleared to an average depth of about 15 feet and this might cost as much as $4.00 per cu. yd., providing that a contractor would bid on it. Assuming that sound rock is present, and that no unforseen complications develop, the slide debris excavation would amount to some $600,000 and the snow shed excavation to maybe $50,000 more. Hence, $650,000 is spent before the snow shed is built. The latter might be built for $300,000 but for the fact that complications are present strongly indicating that the northernmost 100 feet of shed has less than a 50 - 50 chance of surviving another major slide.

14.- In this 100 foot section which we call the "chute area", station 248+00 to 249+00, a great mass of slide debris funneled downward in the 1956 slide. It is bounded on the north side by large expanses of smooth, steeply dipping fault surfaces, and on the south by the upper, so-called "stable island". Recent debris from high up on the slide area has bounded and slid several hundreds of feet down this "chute area". Because of its depth, unknown, but probably in excess of 50 feet, especial construction to afford security of the snow shed would be required, and this cost may be prohibitive. Even then there is no assurance of its success. Assuming that snow shed construction might be approved additional precautions would be necessary; the benching of the upper slide area so the benches slope southward instead of northward, as at present; and either benching of the fault plane surfaces or the construction of south inclined baffles on them to direct debris and snow slides away from the "chute" area.

15.- From the foregoing discussion it is apparent that the cost of a snow shed, including all of the attendant costs, and without substantial hope of permanent security, the costs are probably in excess of 1½ million dollars. In addition, and because the construction season is short, it is inevitable that snow shed construction involves closing of the road through several seasons. In view of all these factors snow shed construction is Not recommended.

16.- TUNNEL CONSTRUCTION

An open road in the slide area is certain to entail steady maintenance, the removal of more major slides, and a positive hazard to the travelling public. Snow shed construction involves the closing of the highway through several seasons, and affords no positive expectation of security because of the dangers of the "chute area". Furthermore the cost would approach or equal that of a tunnel. Therefore, the situation is reached where the only reasonable decision (in this writer's opinion) rests between the construction of a tunnel or the selection of the "low-level" route and bridge at the mouth of Emerald Bay.

The tunnel is estimated to be about 1,100 feet long, mostly on tangent and with a grade of about 7%. It requires a curve near the southern portal where the present highway is joined. This means that lighting may be necessary. All indications are that such a tunnel, as conceived by the Division of Highways, would be beneath all active elements within the slide area, hence safe for year around operation.

The cost of tunnel construction lies somewhere between $1000 and $1500 per lineal foot.

17.- Whereas this writer thinks in terms of a concrete-lined tunnel that does not mean that complete lining is essential. Obviously the portal areas should be lined. Possibly between 10% and 20% of the tunnel will be in granite "crushed" zones, or in fault or joint zones where lining will be essential or desirable. In such sections the contractor will doubtless have to place arch ribs and posts as temporary roof supports. These may later become incorporated in the tunnel lining. Eighty to ninety percent of the tunnel will be in blocky (fractured and broken) granite. This rock, it is believed, can be secured by rock-bolting so that concrete lining in such sections may not be essential. An occassional set of timber bents, or roof supports, may be required in local areas.

Although some water is observed seeping from the slide, and broken granite near station 248+00, both at road level and about 20 feet above the road, water is not anticipated to offer any serious tunneling problem. Naturally, it must be picked up and carried away in a tunnel drain, just as special drainage installations will be necessary at the tunnel south portal. Here the snow melt water must must be removed before it enters the tunnel where icing conditions must be eliminated insofar as possible. The highway grade and tunnel curvature emphasize the importance of this feature.

18.- The construction of a tunnel eliminates the necessity of removing the slide debris above the roadway except in such areas where tunnel protection is needed at the portals. Inasmuch as preliminary planning indicates the portals would be outside of the slide area this problem may not arise.

It is also believed that once the tunnel is driven beyond the portal areas, some sort of one-way traffic can be maintained past the slide area. Of course this would slow down the contractor's operations but is, nevertheless, a factor to be considered.

19.- LOW-LEVEL BRIDGE ROUTE

The proposed line of a low-level bridge route close to the west shore of Lake Tahoe with a bridge across the mouth of Emerald Bay was reexamined. Putting aside all other considerations except those of engineering practibability and highway maintenance this is unquestionably the better route.

The first cut north of the flat point of land at the mouth of

Emerald Bay is through a boulder moraine but there is ample room here to flatten the cut slopes and leave wide shoulders so that boulders would not prevent snow clearance with rotary plows. In contrast, on the present route upslope from Eagle Falls for several hundred feet, north and south of station B-331+47, the water saturated boulder moraine there cannot be touched without inviting a slide of major proportions. Still further northward upslope between stations B-336+47 and 338+80, and north, some width might be gained - up to ten feet - by cutting into the boulder moraine. It is thought this widening might serve chiefly to gain shoulder width.

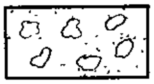
Where the granite cliffs north of Emerald Bay have to be skirted there is a bench along the edge of the lake just below water level that appears entirely satisfactory to support the fill necessary in these areas. The rock in the cliffs appears sound and susceptible to rock bolting in places where such operations might be desirable.

The alignment of the low-level route is excellent and necessitates only very gentle curvature. On the other hand the length of this route indicates a construction period involving several construction seasons and a cost considerably in excess of the boring of a tunnel and the other highway corrective measures contemplated on the high-level route.

Signed:

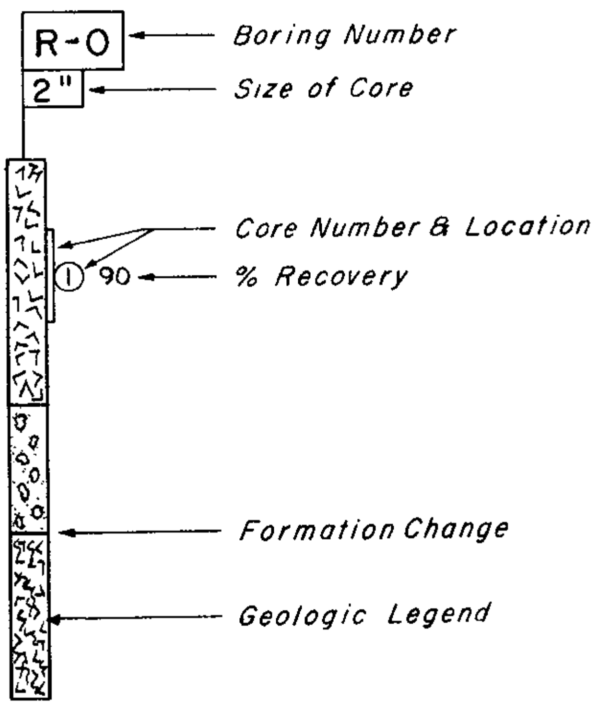
Arthur B. Cleaves
Consulting Geologist

Mod. Hard to Hard Granite



Loose Broken Granite with Decomposed Granite & Sand

Weathered or Decomposed Granite



STATE OF CALIFORNIA DIVISION OF HIGHWAYS
MATERIALS & RESEARCH DEPARTMENT

SLIDE INVESTIGATION
Road III - ED - 38 - B
Emerald Bay
LEGEND SHEET

DWG. No.	SUBMITTED BY:	DATE
57-192-2198	A. W. Root by J. W. Smith SUPV MATLS. & RES. ENGR.	9-16-57
DR. BY: R.P / CK. BY: G.R.	APPROVED BY: F. N. Hveem MATLS. & RES. ENGR.	SHEET No. 1 OF 6 SHT.