

Golden Gate Bridge & Highway District

Investigation of Criticism of Foundation by
DR. BAILEY WILLIS

Report of Building Committee

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GOLDEN GATE BRIDGE & HIGHWAY DISTRICT

November 27, 1934.

Board of Directors,
Golden Gate Bridge & Highway District,
111 Sutter Street,
San Francisco, California.

South Pier - Investigation of criticism
of foundation by Dr. Bailey Willis, Pro-
fessor Emeritus of Geology, Stanford
University.

Gentlemen:

On August 22, 1934, Bailey Willis, Professor Emeritus of Geology, Stanford University, addressed himself to Joseph B. Strauss, Chief Engineer, as follows:

"I am advised by Professor Derleth that certain observations on the geology of the South Pier rock, to which I had invited his attention, were referred to you and members of your Board during the period of July 16 - 19th. You were, no doubt, familiar with these views as presented in a report dated April 7th and addressed to the authorities of the PWA, a copy of which I at that time handed to General Manager Reed.

"I now write to inquire what measures, if any, have been taken or are proposed to obviate the dangers inherent in the geologic conditions described in the reports above cited."

This letter was evidently post-dated as the Chief Engineer responded to Professor Willis on August 17th, informing the Professor that the facts relating to the south pier were public records, and the latter requested opportunity to examine the records, particularly as related to "soundings and borings and to the design of the pier with special reference to any facts that bear upon the condition of the rock under the pier or that illustrate measures taken to guard against landslides which may endanger the structure." (Willis' letter to Strauss, August 16, 1934.)

The Chief Engineer took the position that he would not discuss engineering problems with Professor Willis, that the subject was outside Professor Willis' experience and had been, and was being satisfactorily solved by the consulting engineers and himself. This was dated September 3rd, copy of which was transmitted to the Chairman of the Building Committee with the suggestion that "it might be desirable to bring the matter to a head" and to "compel him to state the cause and purpose of his interest****".

In conferring with the Chief Engineer, the Chairman of the Building Committee suggested that it would seem to be the preferable course to suggest a hearing before that Committee to develop the problems involved for the purpose of reporting to the Board of Directors. Meanwhile, hoping to check misleading publicity, if not to convince the Professor that the south pier foundation was satisfactory, arrangements were made for hearing and the Professor was contentious even as to who had suggested it. That he should desire to present his case seemed a reasonable presumption, but it is immaterial.

The Chief Engineer, after conference with the Chairman of the Building Committee, informed Professor Willis that, if he desired, the Chief Engineer would request a hearing before the Building Committee. He also informed him subsequently that hearing had been arranged.

In the meantime, Professor Willis telegraphed the Board of Directors, urging that operations at the south pier site be suspended until further consideration could be given to conditions which he said endangered the permanent security of the Bridge.

A reference to chronology is essential. On the 7th day of April, 1934, Professor Willis sought an interview with President Filmer relating to a "report" he had prepared on the Golden Gate Bridge South Pier Foundation. He was referred to General Manager Reed and the president requested the chairman of the Building Committee to be present at the interview. At this interview, Professor Willis delivered to the General Manager a copy of the aforesaid report entitled "Golden Gate Bridge: Foundation of South Pier" dated April 7, 1934, addressed to Mr. A. D. Wilder, Assistant State Engineer, 614 State Building, San Francisco. The addressee is Col. Wilder, U. S. A. This report will be the subject of comment subsequently herein. The Professor expounded upon the report and on the same day delivered the original to Col. Wilder. (Transcript 1, page 19; transcript 2, pp. 52, 53 and 54.) This is of interest for two reasons. The District authorities had applied to the PWA for a grant of funds to be used in expediting construction of the south approach and had also requested the purchase of District bonds up to a total of \$6,000,000.00. The application and the request were pending when Professor Willis' report was made to Col. Wilder.

An extensive campaign of education was conducted during the fall of the year 1930 prior to the election on November 4, 1930, at which time the people voted in favor of the bond issue. At this time Professor Willis was a resident at Stanford University. (Transcript 1, page 13.) A question addressed to Professor Willis and his answer at the first hearing before the Building Committee are quoted, (Transcript 1, page 5, September 28, 1934):

"Q Coming down to this Golden Gate Bridge & Highway District: You have been familiar, I imagine, to some extent with the history of the Bridge District, have you not?

"A I think it first came to my attention about three years ago. Of course, I read in the newspapers what everybody knew. Some three years ago, in the Engineers Club, I was asked by Mr. Kinzie what I knew about serpentine, and I had no knowledge at that time about the geology of the bridge site, or the conditions of the foundations or of the dispute here, but I answered him in regard to serpentine.

I have since learned that there was a question in his mind as to the security of it, because it was on serpentine. I told him what I considered to be common knowledge; namely, that serpentine is a treacherous and uncertain rock, and that it is one which should be very carefully investigated before any load is put upon it."

He had, however, in 1931 when Professor Sedgwick had come to San Francisco, had some discussion with Professor Sedgwick relating to his study of the south pier area. Notwithstanding the publicity attendant upon the bond issue campaign, particularly the attack on the south pier site, and subsequent litigation, the Professor evinced no further interest until approximately March 8, 1934, after he had been cooperating with the Safety Committee of the Junior Chamber of Commerce in a study of earthquake conditions. (Transcript 1, pp. 8 and 9.)

As the result of study in cooperation with the Chamber Committee, he concluded that the safety of any structure placed on a knob of rock out in the bay was subject to very grave question and he conferred with Mr. A. J. Cleary, Chief Administrative Officer of San Francisco, and thereafter he consulted Col. Wilder, the California representative of PWA, and stated:

"The reason for that suggestion on Mr. Cleary's part was that there was a loan pending -- an application for a loan -- before the PWA, and he and I both felt that they should know the facts. In response to Mr. Wilder's request, I wrote a report on my observations of faults here***". (Transcript 1, page 10.)

This knob of rock Professor Willis characterizes as "pudding stone" in statements appearing in the press and elsewhere. (Transcript 1, page 24, line 20.)

In the last week of April, he saw Mr. C. McDonough of the Public Works Administration, Engineering Director, and called on him early in May (transcript 1, page 11.) It was after that that he made an effort to communicate with the bridge authorities. It was not until September 6th, after an inter-change of correspondence with Professor Derleth and Chief Engineer Strauss, that he visited the Bridge District office, and at that time there was an interview between Mr. Felt and the Professor and he proceeded to the bridge-head to examine drill cores and thereafter verified his observations along the west shore, particularly in regard to landslides. He then went to the Coast & Geodetic Survey and obtained photostats and soundings and made an analysis of these soundings. (Transcript 1, page 12.) The following excerpt from the transcript is pertinent to the subject:

"Q Do you think that it would have been a good policy to pursue, to make a study of what the Bridge District had done under the advice of its experts before you came to a conclusion and rendered your report to Col. Wilder?

"A If I had felt that I could get full and adequate information in regard to this project, I would certainly have asked for it.

"Q Well, why didn't you ask for it?

"A Because I understood that the project was one which was being promoted from the start; and that you were committed to the construction of the bridge, and that information was not readily obtainable. In regard to the latter item, I may say that my experience of the last six months has confirmed that impression." (Transcript 1, page 18.)

Professor Willis was awarded the degree of Mining Engineering at Columbia University in 1878 and in 1879 the degree of Civil Engineer. He has never done any construction work or any designing, nor has he engaged in preparation of specifications as related to construction. (Transcript 1, page 6.)

Based upon his concept of the geology, Professor Willis makes the following observations and recommendations:

"To make perfectly clear what I think is the one line of action which can complete that bridge: I think you will have to go down into the rock with your foundation to the level of the bottom of the channel, in order that you may put that foundation upon the same general broad basis that the transbay piers rest upon. They are on the bottom of the channel, and they are safe. A pier placed on top of that rock I think would not be safe."

"Q What is the depth of the channel at that particular Place?

"A You would have to go about 250 feet below where you are now, so far as I am informed. My information as to your project, when it comes down to engineering details, is very inadequate, because I haven't been informed; my questions have not been answered." (Transcript 1, pp. 14-15.)

Professor Willis recommends the appointment of an impartial federal commission to investigate and determine the facts. (Hearing of October 22, 1934 - transcript 2, page 50, line 14.) The Building Committee conducted hearings September 28th, October 22nd and October 30th, 1934. The hearings were attended by Thomas L. Maxwell and the Chairman of the Building Committee, Mr. Hugo Newhouse, Director, James Reed, General Manager, W. W. Felt, Secretary, Joseph B. Strauss, Chief Engineer, George H. Harlan, District Counsel, Russell Cone, Resident Engineer, Professor Andrew C. Lawson, geologist, Professor Charles Derleth, of the Board of Consulting Engineers, and Dr. Bailey Willis, Professor Emeritus of Geology, Stanford University. In addition to these, Professor Allan E. Sedgwick, Consulting Geologist, of the University of Southern California attended the hearing on October 30th. The geologists, Resident Engineer Cone, Director Newhouse and the chairman of the Building Committee accompanied Professor Bailey Willis on an exploration of the shore from Fort Point to Marshall Beach Friday, October 26th. Mr. Gardiner of the Norwich Fire Insurance Company and a member of the Junior Chamber of Commerce was also present.

Professor Willis has supported his recommendation by his concept of the geology of the area. It seems that his concept has changed from time to time. In the report addressed to Col. Wilder his conclusions are:

"1. There is no geological reason to assume that earthquake vibrations may probably cause the structure of the Golden Gate Bridge to oscillate in a manner likely to cause its failure. It is about six miles from the San Andreas rift and about twelve miles from the Hayward's rift, and there is no nearer fault of such character and magnitude as would react with sufficient violence to affect the structure.

"2. The southern anchorage and the south pier are founded upon a mass of sheared rock involved in a system of minor faults and consequently unstable to a degree likely to endanger the structure. The rock is serpentine and is subject to landslides, as may be seen in the immediate vicinity. Slides have occurred under natural conditions. The probability of their occurrence has been increased by blasting and would be gravely augmented by the weight of the structure it is proposed to erect on the foundation of the south pier. Such a slide would, to a greater or less extent, block the entrance to San Francisco harbor, change the tidal prism, and consequently the level of tides, and would seriously affect the future of the City as well as cause the loss of the bridge.

"3. This danger can be overcome provided the foundation be carried in the rock to the depth of the adjacent channel or below it. It would appear practicable to do this by adopting the expedient used in sinking foundations through deep alluvium; that is, by drilling out wells and filling them with reinforced concrete. It would be necessary that the columns thus constructed should be of sufficient strength to carry the load and of such resistance to transfer shear as would prevent a landslide."

In this report there is no exact location of the contact between the serpentized peridotite and the undefined other rock observed on the west shore of the Presidio reservation as related to the Golden Gate pier, except that it extended down into the channel and "must cross the line of the Golden Gate bridge somewhere north of the south pier." Professor Willis was concerned with the condition of the serpentized peridotite in the mass and under water "for that is the condition of the foundation to be considered." (Report of April 7, page 3.) He then described the conditions appearing to exist in the mass of serpentized peridotite "which constitutes the foundation of the south pier of the Golden Gate bridge." He describes the serpentine underlying the foundation in this report as having two weaknesses, - - it is under an internal stress which reacts with an external force to produce rupture, and it is also transversed by planes of concentrated shear which are irregular and result in open fissures as a consequence of displacement, and that landslides are characteristic. He discusses landslides that are "characteristic of all exposed parts of the formation" and continues:

"It would appear that there is reasonable ground to fear that a structure thus supported must sooner or later be destroyed by landslide, either as a result of prolonged stress and fatigue of material or as a result of earthquake shock, or both."

Later he describes the rock as "pudding stone" and claims that "in the mass it squeezes and slips, producing very smooth, slippery fractures which are known by the old Cornish mining term as 'slickensides.'" (Willis' report October 7th.)

In the map contained in the report to Col. Wilder, there is a section through San Francisco projecting the San Andreas Rift, the connecting Tamalpais Spall and an "auxiliary Fault." It is only of interest to note that on the map, which may be called a plan of the faults and spalls, the "Auxiliary Spall" referred to passes along the western shore of Presidio reservation proximating the out-cropping of the sandstone, which will be referred to, and passing southeast of Fort Point out into the bay.

At the hearing held September 28th, Professor Willis enlarged on the possibilities of slides of the structure upon which the south pier is located and claimed that slides "carried away the face of that slope there, and caused a recession of the front amounting to 150 feet; they caused a difference of depth of over 50 feet immediately north of the site of the pier." (Transcript 1, page 26.) and that this had happened between 1895 and 1920. He stated that his observations had been based upon hydrographic sheets furnished by the Coast and Geodetic Survey.

With reference to the alleged recession and the fault, using the term "alleged" without any purpose of reflecting on the veracity of the Professor but merely to indicate that the existence of the fault and any recession must be proved, there are some very interesting facts. The Professor has proceeded by analogy and by use of Coast and Geodetic Survey sheets to establish his claims. Maintaining that serpentine is unstable and subject to slides, he states that this is demonstrated by slides which have occurred on the bluffs of the shore west of the Presidio reservation. Professor Lawson asserts unhesitatingly that these are not landslides, are totally different from landslides and due to sea action (transcript 1, pages 57-58), that is to say, that the cliff undermined by the sea falls of its own weight. It is Professor Willis' claim that if the formation slides in one place, it will slide in another and that there have been slides from the formation in the vicinity northwest of the south pier. Viewing the area of exposed serpentine south of the Fort and the bluffs that have stood for ages without sliding, except where subjected to sea action including the points referred to by Professor Willis, it at least raises some question as to the sliding of serpentine, particularly in view of the fact that it is exposed to weathering processes.

In passing, reference should be made to possible swelling of the serpentine. Professor Willis claims that the process of decomposition continues, with which Professor Lawson is not in agreement, claiming that an analysis of the specimen shown would show that it contained from 13 to 14 per cent of water (transcript 2, page 6) and that hydration process has been completed for ages. It

evidently has gone on to some extent under the south pier because Professor Willis has testified that the diamond drill borings show that a large portion of the rock consists of soft material. (Transcript 2, page 7.) As to the portion of soft material, there is a difference of opinion between the geologists. Reference is made to this merely as related to possibility of swelling because Professor Willis asserts that as the process of decomposition goes on the rock in swelling closes the fissures and shears. (Transcript 2, page 7.) So far as he has knowledge of the structure, it would seem that, the process being complete, there should be little or no danger of further swelling or shearing. Nevertheless, as related to swelling, Professor Willis, answering an inquiry based upon the supposition that decomposition process continues, "Would the swelling be perceptible?", replied, "Probably not in any time that you could measure." (Transcript 3, page 38.)

The ravine which Professor Willis describes northwest of the pier site, he states indicates a fault and that that fault is along the contact of an alleged sand-stone extending west and north of the pier and dipping easterly, and the serpentine, and he claims that the ravine indicates soft material with hard material to the west of it. (Transcript 3, page 16.) He also refers to harder material to the east of it forming a promontory (upon which promontory it happens that the pier is located) but he does not describe that material which the operations of the bridge contractors have definitely demonstrated to be serpentine.

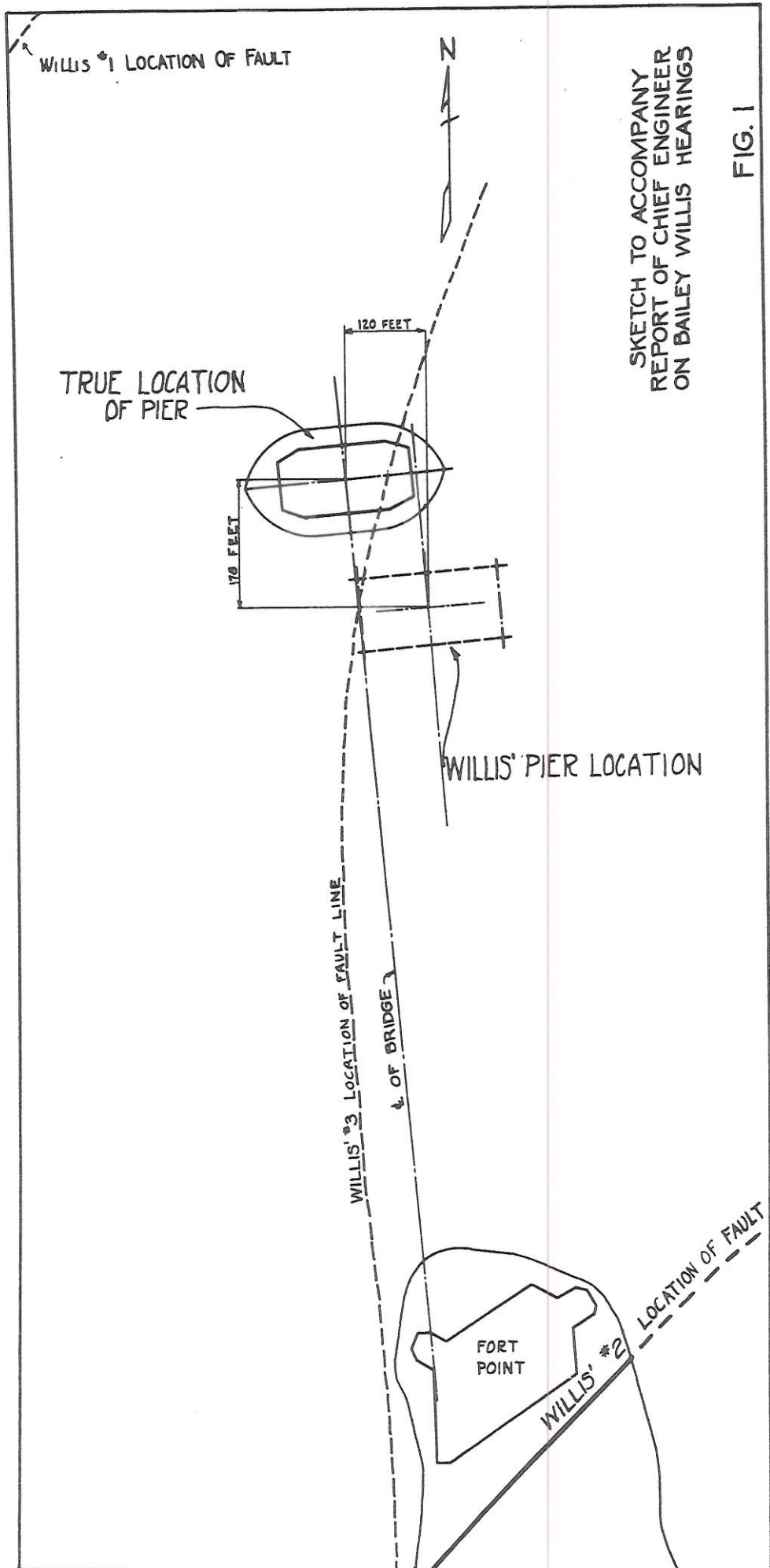
In his process of analogy, he points to contact between sandstone and crushed slate and serpentine at Marshall Beach, which is some 1500 feet south of the Port on the west side of the reservation, and contends that it extends out beyond the south pier between the serpentine and the sandstone. (Transcript 3, pp. 17, 19, 20, 27, 28, 29, 30.) Neither the sandstone nor the fault has been traced under water. Reference to projecting the same on maps by Professor Willis will be referred to hereinafter.

Professors Lawson and Sedgwick have reported with reference to the photograph of this fault near Marshall Beach:

"When we examined it in the field, the alleged fault proved to be merely a narrow dike of serpentine, exceptionally decomposed and partially silicified with sandstone on both sides of it. The width of the dike is about five or six feet. It is merely a narrow, intrusive tongue of serpentine in the sandstone, an offshoot of a greater body of serpentine and has none of the characteristics or features of a fault."

It is questionable, to say the least, if it is a fault. That it extends along the shore and out into the sea west of the pier site is based upon analogy.

As related to the alleged sliding northwest of the pier and the existence of a fault at that point, which is also predicated upon another layer of sandstone to the west of the fault line, it is necessary to refer to a map prepared by Professor Willis for the District and presented at the hearing September 28th on which were plotted the south pier and the so-called ravine, the layer of



SKETCH TO ACCOMPANY
 REPORT OF CHIEF ENGINEER
 ON BAILEY WILLIS HEARINGS

FIG. 1

sandstone and the fault between the sandstone and the serpentine. These projections are upon an enlargement of a section of a sheet of the Coast and Geodetic Survey. (Exhibits 9, 9-a and 9-b.) The map as originally presented projected all these features and there was but one fault line. It was thereafter demonstrated that Professor Willis had made an error in location of the south pier, that he had located it by "general information", that he had placed the pier as near as he could on the diagram "not considering that for geological purposes that the exact location of the pier was a matter of very much consequence", and that he had found, as he had been told after introduction of the map, that the pier was located 178 feet north and 120 feet west of the location which he had shown. (Transcript 3, page 8.) Exhibit attached. (Fig. 1.)

The fault line projected on Professor Willis' original map would have passed directly through the south pier correctly located. When Professor Willis re-ramped the map he moved the fault line west and this represented the progress of his studies in the interval between September 28th and October 22nd which had also developed other faults which were delineated on the map showing the correct location of the pier. (Transcript 3, page 12.)

One may be pardoned the impression that this embarrassment might have been avoided by an investigation of the records of the district and that it is too bad that conclusions based upon the error had been transmitted to FWA authorities and the public through the press. Professor Willis' comment was that the correct location had placed the south pier on a more shattered portion of the serpentine and nearer the major fault. (Transcript 3, page 9.)

Reference to the plan in the report made to Col. Wilder by Professor Willis indicates only an "auxiliary spall" passing southeast of Fort Point, well inside the location of the south pier, and there is no "contact fault" projected west of the pier. In the section in that same report there is projected the "Tamalpais Spall" connecting with what he designates the "San Andreas Rift." Concerning this, Professors Lawson and Sedgwick comment "that Professor Willis evidently was not aware of the existence of a very large fault, the San Bruno Fault, which intervenes between the San Andreas Fault and the Golden Gate and which was described many years ago." Reference to this is justified, it would seem, as indicative of inaccuracy.

Professor Willis referred to a disparity in profile or contour of the formation northwest of the south pier site, claiming a difference between the profiles as indicated by contours in the surveys of 1895 and 1920, and that this disparity indicated a recession due to slides. These findings were checked and it is demonstrated that Professor Willis was again in error and that there had been no substantial, if any, changes in the contours between 1895 and 1920. (Transcript 3, page 57 and exhibits.) Professor Willis, admitting one error, commented:

"On the east-west profile, we found that I had read an obscure two as a one." (Letter November 7, 1934, addressed to Chairman, Building Committee.)

He also claimed that there was no error in his delineation of the north-west profile, but this does not accord with the checking of the District engineers. The misreading of the obscure numeral by the Professor, as the numerals related to fathoms, made a difference of 60 feet. (Transcript 3, page 62.) Exhibit attached. (Fig. 3)

Professor Willis replied, in answer to a question, that if the profile was identical, in that event his assumption there would be incorrect. (Transcript 3, page 67.)

The profiles were taken from the Coast and Geodetic Survey. (Transcript 3, page 59.) The Board should be informed that hydrographic surveys made by the Bureau of the Coast and Geodetic Survey are not for engineering purposes.

"More care must be taken to eliminate even small errors which might be caused by special conditions such as, in this case, the strong currents which are prevalent in the area under consideration* * * *".

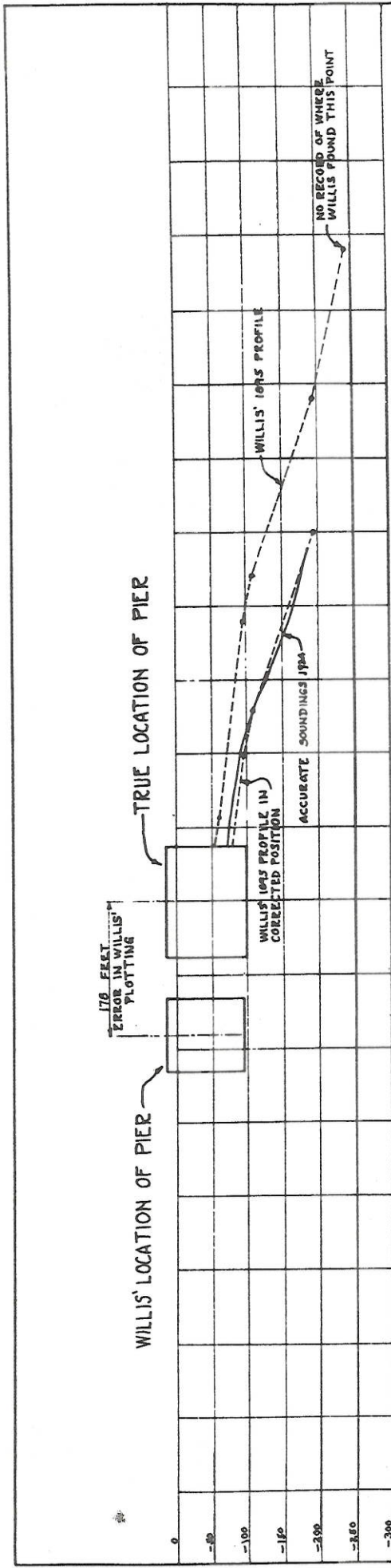
"Our hydrographic surveys are frequently used for comparison to show general changes in depth which have occurred but it is always necessary to use extreme care in making such comparisons. The type of survey, conditions, methods and procedure must receive careful consideration. A comparison between the results of modern surveys and those made many years ago has always been open to question on account of the lower standards prevailing in the past. An examination of the surveys of 1895 and 1920 in this office indicates that they do not provide an exception to these general rules, and it is the opinion of this office that they should not be relied upon to furnish the exact engineering data required in this case." (Quotation from letter from Director of the Coast and Geodetic Survey, transcript 3, page 70.)

Mr. Maher, Inspector, Coast and Geodetic Survey, stated in a letter that:

"Sextant angles taken by observers at fixed intervals were used to locate certain soundings * * * *".

For more scientific comment on the alleged fault and fault canyon, reference is made to the report of Professors Lawson and Sedgwick, dated November 13, 1934, addressed to the Board of Directors, as a part of this investigation, and the supplementary report by Professor Lawson addressed to Joseph B. Strauss, Chief Engineer, dated November 21, 1934.

It is again demonstrated that it is unfortunate that Professor Willis did not avail himself of data which is available at the Bridge District office. He was unaware of the extensive exploration of the area about the south pier which was made under the supervision of the District Engineers to determine exactly the shape and character of the structure on which the south pier is located, particularly



PROFILES ALONG ϕ OF BRIDGE
HORIZONTAL SCALE SAME AS VERTICAL

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FIG. 3

with reference to instigated persisting rumors of the existence of an immense re-entrant cavern under the serpentine supporting the south pier. (Transcript 2, page 40.)

The soundings were taken on lines or ranges radiating from the periphery of the excavation for the pier and fender. These extended in an arc from southwest of the perimeter of the excavation to southeast thereof, a total of 270 degrees. From southwest to northwest the soundings extended for a distance of 200 feet out from the excavation, and from northwest to southeast they extended 400 feet out. In the west sector, the soundings were made on 20 foot centers, in the sector from northwest to southeast, for a distance of 300 feet out, they were made on 20 foot centers and for a distance from 300 to 400 feet out they were made on 50 foot centers. Six hundred soundings were made with a 2500 pound weight attached to a steel line at points established accurately by shore triangulation and from a barge securely fixed by six heavy anchors. The result was that the contours upon which the location of the pier was based were confirmed and additional intermediate contours established. At all low points divers descended to check within a radius of 20 feet from the sounding anchor. This would dispose of the assertion of Professor Willis in his report received November 23rd that deep "potholes" were discovered.

Granting that Professor Willis had met with opposition and obstruction in his efforts to obtain data, (which is not evident though there are indications of natural resentment on the part of the Chief Engineer who had not been addressed by Professor Willis prior to the post-dated letter of August 22, 1934, which was more than four months after the report made to Col. Wilder by Professor Willis,) as Professor Willis, himself, insists the problems he had in mind were important, he should not have been so easily diverted. (Transcript 3, page 42.) He should have been as persistent in that as he has been in other directions. He did see the blue print of the soundings which was exhibited to him by Mr. Felt on August 28th, but evidently its importance did not impress him. (Transcript 3, page 45.) He felt that he should have been granted "special privileges," (transcript 3, page 45) - to what extent is not developed. He was accorded every courtesy when he did call and only he could have determined on the necessity of more frequent calls.

As may be surmised, if not definitely so stated heretofore in this report, Professor Willis claims that the alleged sand-stone, which he has projected as extending to the west of and beyond the site of the south pier, slopes southeast under the pier. He asserts that the serpentine superimposes this sand-stone, that the structure is faulted between the sand-stone and the serpentine, that the slope goes off steeply and that the pier which is to support the greatest bridge ever built is to rest upon a slippery incline on the edge of an abyss (from a statement accompanying a letter addressed to W. W. Felt, Jr., Secretary, dated October 7, 1934, signed "Bailey Willis".) The existence of this sand-stone is based upon analogy. There has been no taking of specimens and in so far as that particular sand-stone is involved, it is a guess. (Transcript 2, pages 28, 30, 36, - (lines 5-13, 18-22) and 39.)

There is sandstone which is exposed on the cliff and in the excavation

south of the anchorage. This sand-stone strikes east and southeast from the anchorage and slopes south. This layer could not, therefore, underlie the pier. Professor Willis had not seen the exposure in the excavation for the anchorage. (Transcript 2, page 27.) After this fact was developed Professor Willis claimed that there was a serpentine intrusion and that there is a sand-stone underneath the serpentine upon which the anchorage, the Fort and the pylons rest and which underlies the south pier. Exhibit attached. (Fig. 3.)

He alludes to islets skirting the shore which he claims are sand-stone. There are two very small islets southwest of the anchorage, the most northerly of the series of islets, which are sand-stone. The Professor exhibited a photograph sighting from the shore line through these northerly islets to a point west of the south pier site and bases his claim that the sandstone extends in the same general line upon the existence of these islets. The fact is that a plan of the islets and a photograph taken in the opposite direction demonstrate that there is a general curve toward the shore which, projected, would coincide with the strike of the exposed sandstone.

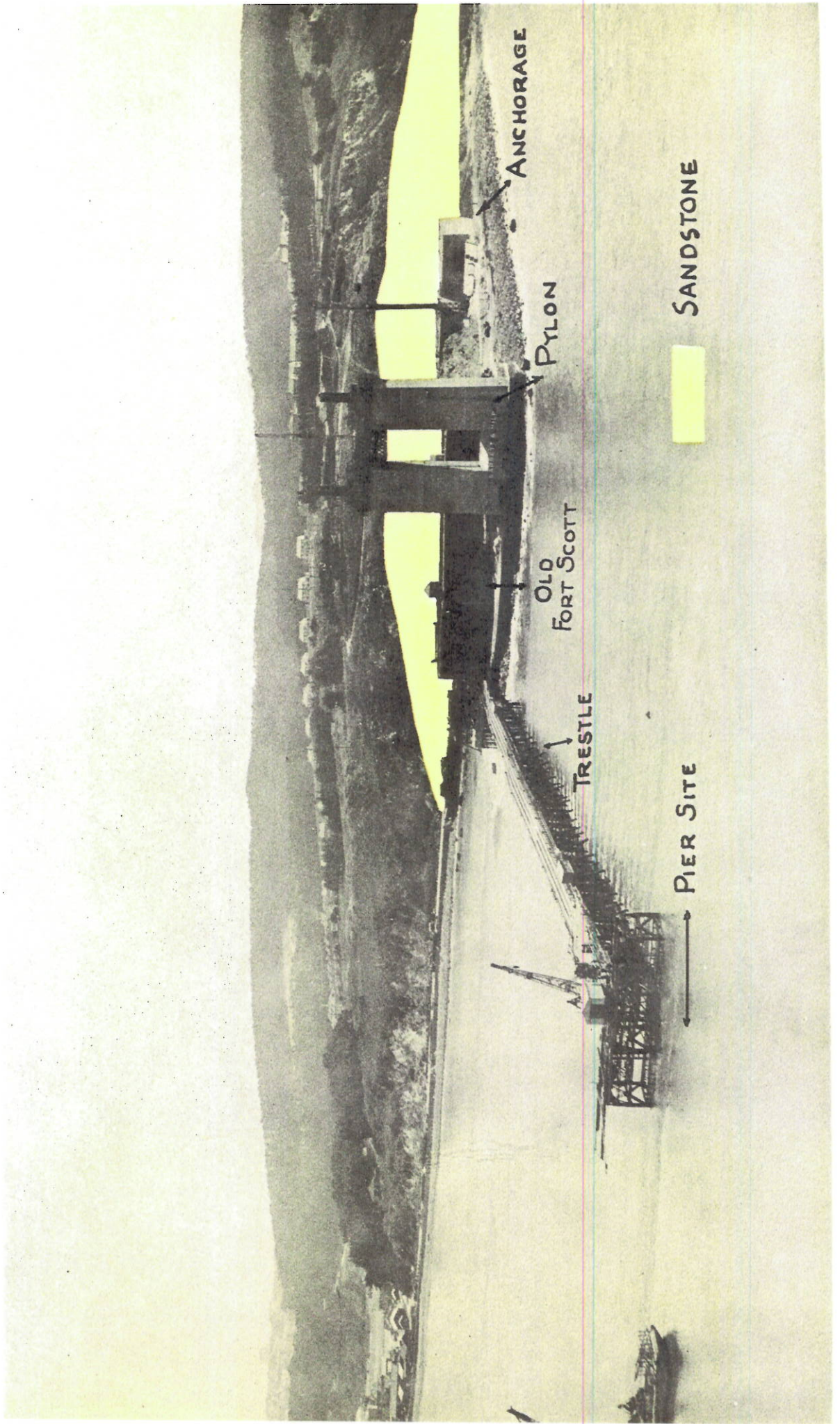
Professor Lawson claims that these northerly islets, at least, are "loose blocks of the hard sandstone which have been detached from the main formation in the course of cliff recession." (Lawson-Sedgwick report, November 13, 1934, page 6.) If they were, in fact, out-croppings of the second layer of sandstone, which Professor Willis alleges to exist, this underlying sandstone as it skirts the shore line should have been exposed in the excavation for the anchorage which extended to a depth of 45 feet below water level. No sandstone was uncovered. The excavation was entirely serpentine. It has been demonstrated that some of these sandstone masses in the water just off shore rest on serpentine. (Lawson-Sedgwick report, November 13, 1934, page 6.)

Professor Willis claims that the contours indicate a harder rock to the west of the alleged fault which must be sandstone plateaus because they indicate that the water is shallower, but the same contours indicating the same shallow water extend over the portion which he admits to be serpentine.

Professor Willis projected this underlying sandstone in an east-west section through the south pier in an article appearing in the Argonaut, October 19th, pending the hearing. It developed at the hearing, October 22nd, that the section was erroneous. This section was published in the Argonaut as an ocular demonstration that the south pier would rest on serpentine superimposed upon a slippery fault over sandstone. It was not only erroneous as to the depth of the water, but exaggerated the slope. If the pier was drawn to scale, the sandstone should be exposed within approximately 30 feet below the westerly end of the pier and within approximately 75 feet of the easterly end of the pier.

He indicated the depth of the channel to be 340 feet in this section, when, as a matter of fact, it is 241 feet, being a difference of approximately 100 feet. Exhibit attached. (Fig. 4)

It is not difficult to conceive of the impression created by the exaggerated slope and the error in depth. It is true that there is 340 feet of water in the



ANCHORAGE

PYLON

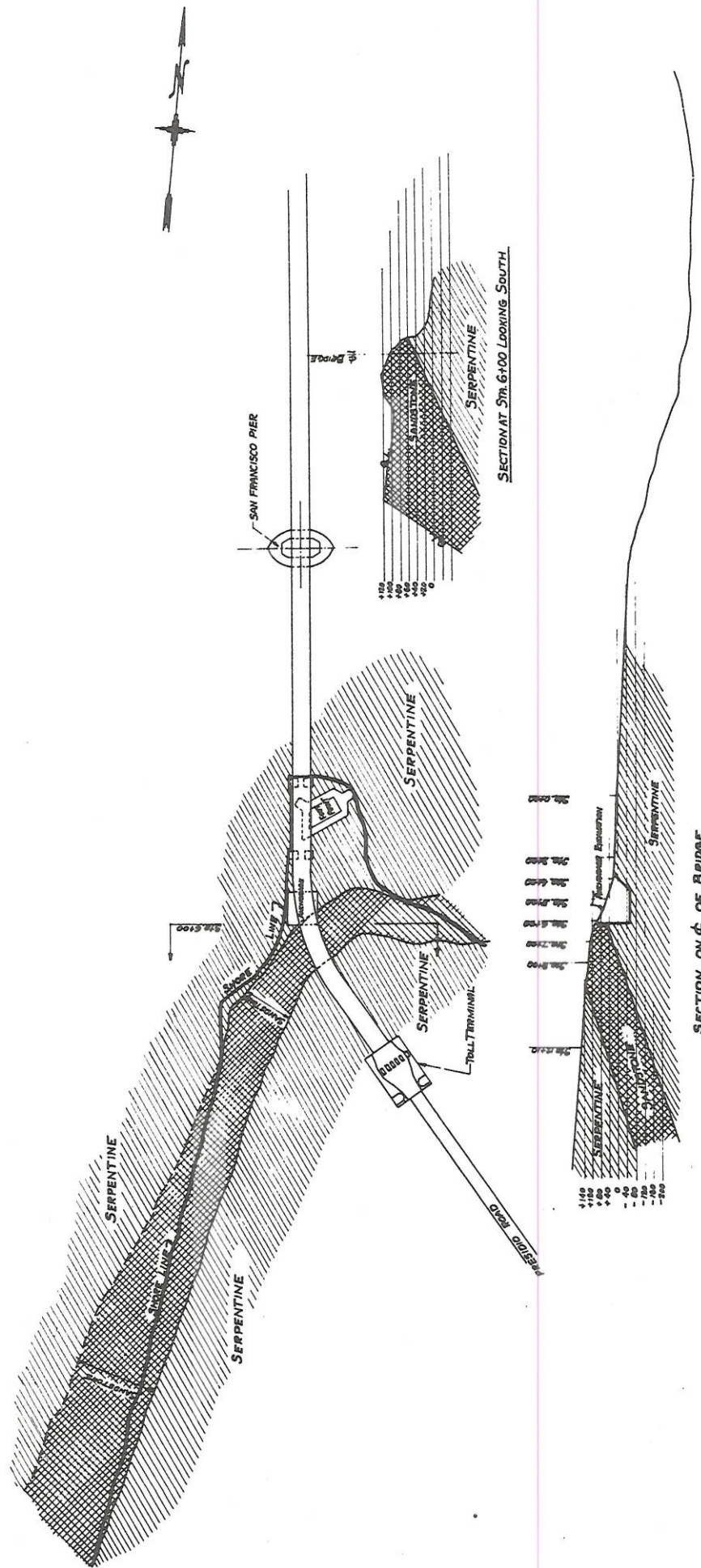
OLD
FORT SCOTT

TRESTLE

SANDSTONE

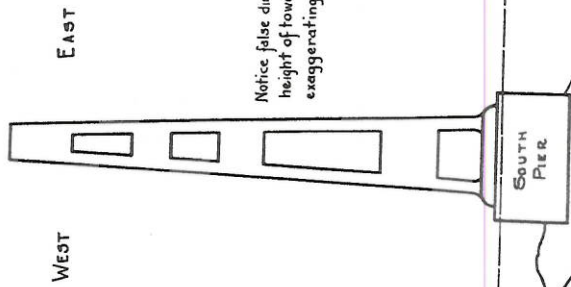
PIER SITE





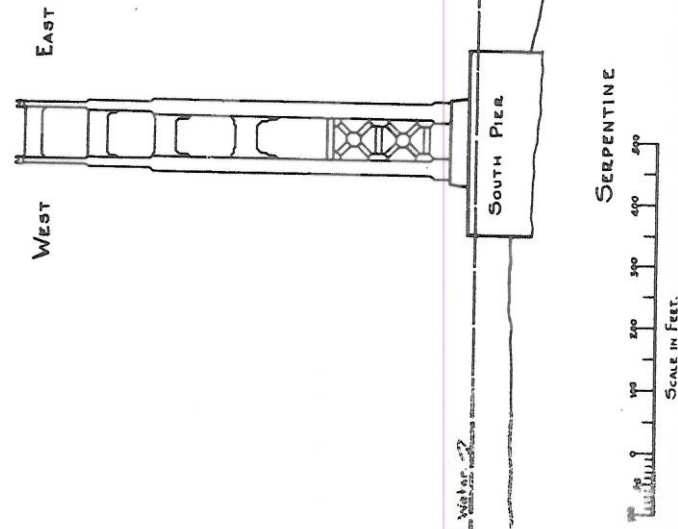
SKETCH TO ACCOMPANY
 REPORT OF CHIEF ENGINEER
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 FIG. 2

WILLIS' LOCATION.
 REPRODUCED FROM ARGONAUT
 Oct. 19, 1934.



Notice false dimensions, in depth and location of channel, height of tower, and size of pier for the purpose of exaggerating alleged instability.

ACTUAL SECTION.



SKETCH TO ACCOMPANY
 REPORT OF CHIEF ENGINEER
 ON BAILEY WILLIS HEARINGS
 FIG. 4

channel, but it is northeast. This was depicted by the Professor in an article prepared for consumption of the public as being an east-west section. It was not only erroneous, but the so-called dangers were exaggerated.

Professor Willis also exhibited a model of the formation on which the pier is located, the design being based upon Coast and Geodetic Survey maps (transcript 3, page 44), but with a peculiarity that the vertical was exaggerated 5 to 1. (Transcript 2, page 42.) This would have the effect of increasing the slope, and, unless one may visualize the actual slope with the knowledge of an engineer, is deceptive. It is difficult to conceive the purpose, particularly if it were intended for information of the public. It not only exaggerated the slopes, but exaggerated the so-called gulleys and canyons. A print was also reproduced in the Argonaut. The south pier was projected thereon incorrectly and had the appearance of being perilously near the edge of a steep bluff. That was the effect of exaggerating the vertical. (Transcript 2, page 45.)

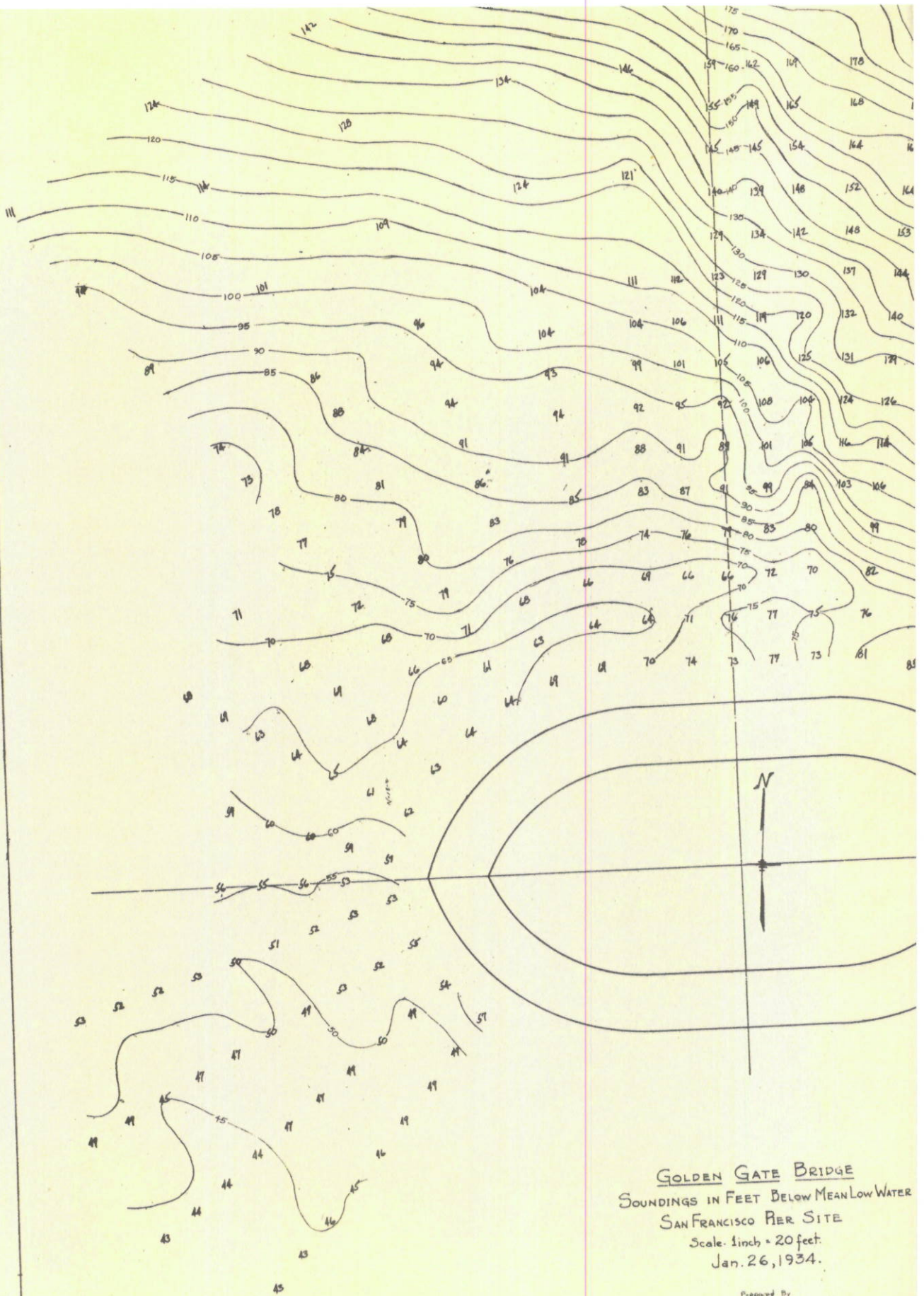
This report is not intended as an arraignment of Professor Willis. It is merely a statement of the facts which were developed at the hearings and in the reports which were submitted by Professor Willis, with the intention of being entirely fair. The reports of Professor Willis, available to the Directors are: copy of that submitted to Col. Wilder dated April 7, 1934; statements transmitted to Secretary Felt for the information of the Directors of the District, with a letter dated October 7, 1934; a report entitled "Geology of South Pier Site" received at the Bridge District office November 23, 1934. It would not be presenting a complete picture if reference were not made to some other incidents.

During the progress of the hearing, the officials of the District followed the policy of not issuing any statements, desiring to restrain all comment until the investigation had been completed. It was not so with Professor Willis. The newspaper clippings of his public pronouncements received at the District office give evidence that he was prolific in that respect.

While the hearings were in progress, with the berthing of the caisson as a motif, he issued statements to the press which he stated had been prepared for the Building Committee, but, in view of the proposal to berth the caisson, he felt obliged to anticipate that opportunity and to present the facts to the Directors immediately. References have been made to these statements. He also, under date of October 11th, referring to a circular relating to the issue of \$2,000,000.00 Series B 4-3/4% Bonds of the Golden Gate Bridge and Highway District, dated July 1, 1934, addressed a letter to Charles Blyth, of Blyth and Company, a member of the Bond Syndicate, inviting attention to these statements immediately referred to. He also requested Mr. Blyth to examine the model which has been the subject of comment in this report, then on exhibition at the Engineers Club:

"Which will enable you to visualize the conditions more clearly * * * *

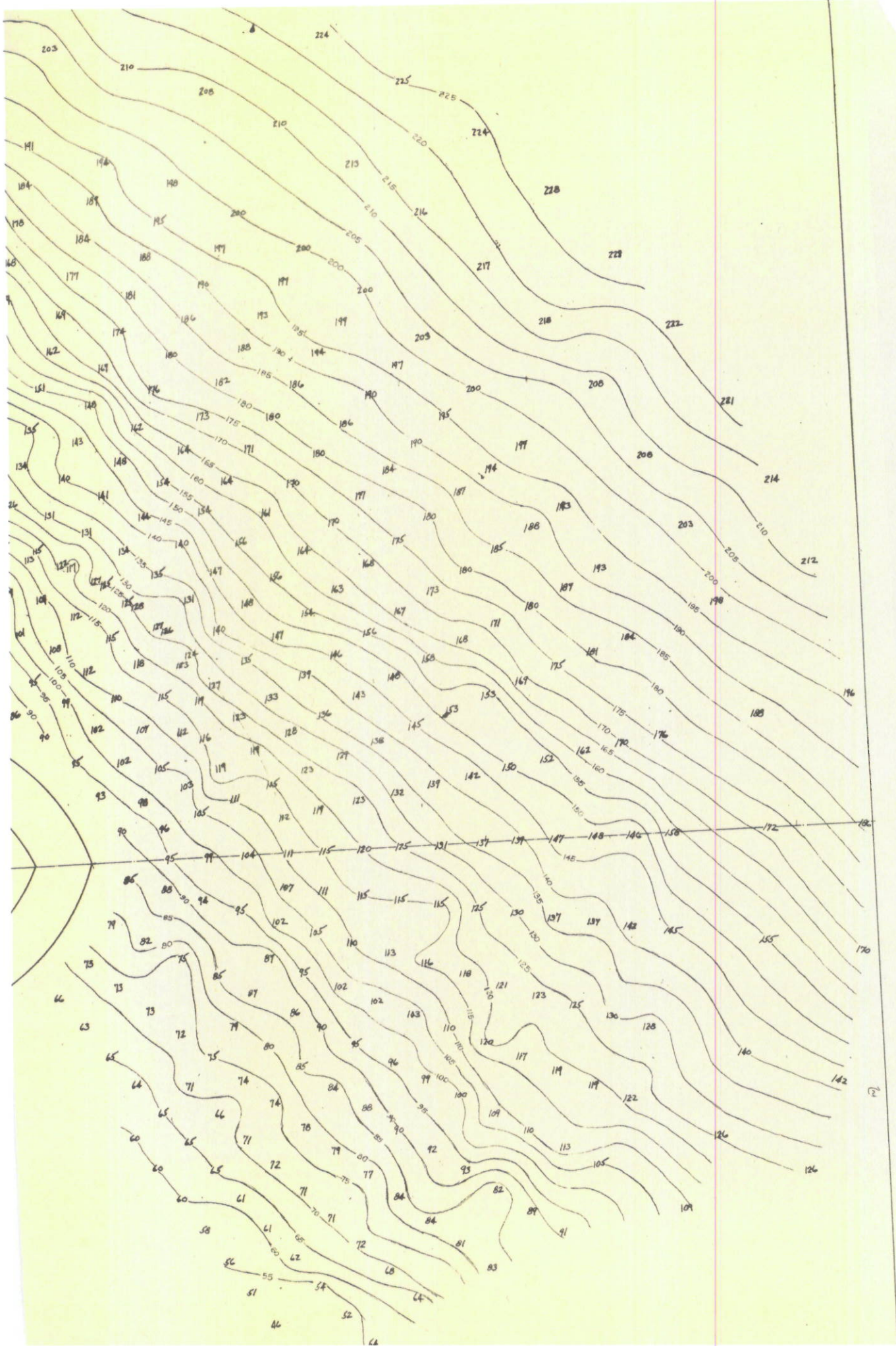
"This information is submitted to you in order that the banks and the public may not be misled into the purchase of bonds whose value depends on the completion of the Bridge on a stable foundation. As the Bridge is now designed that foundation does not exist."

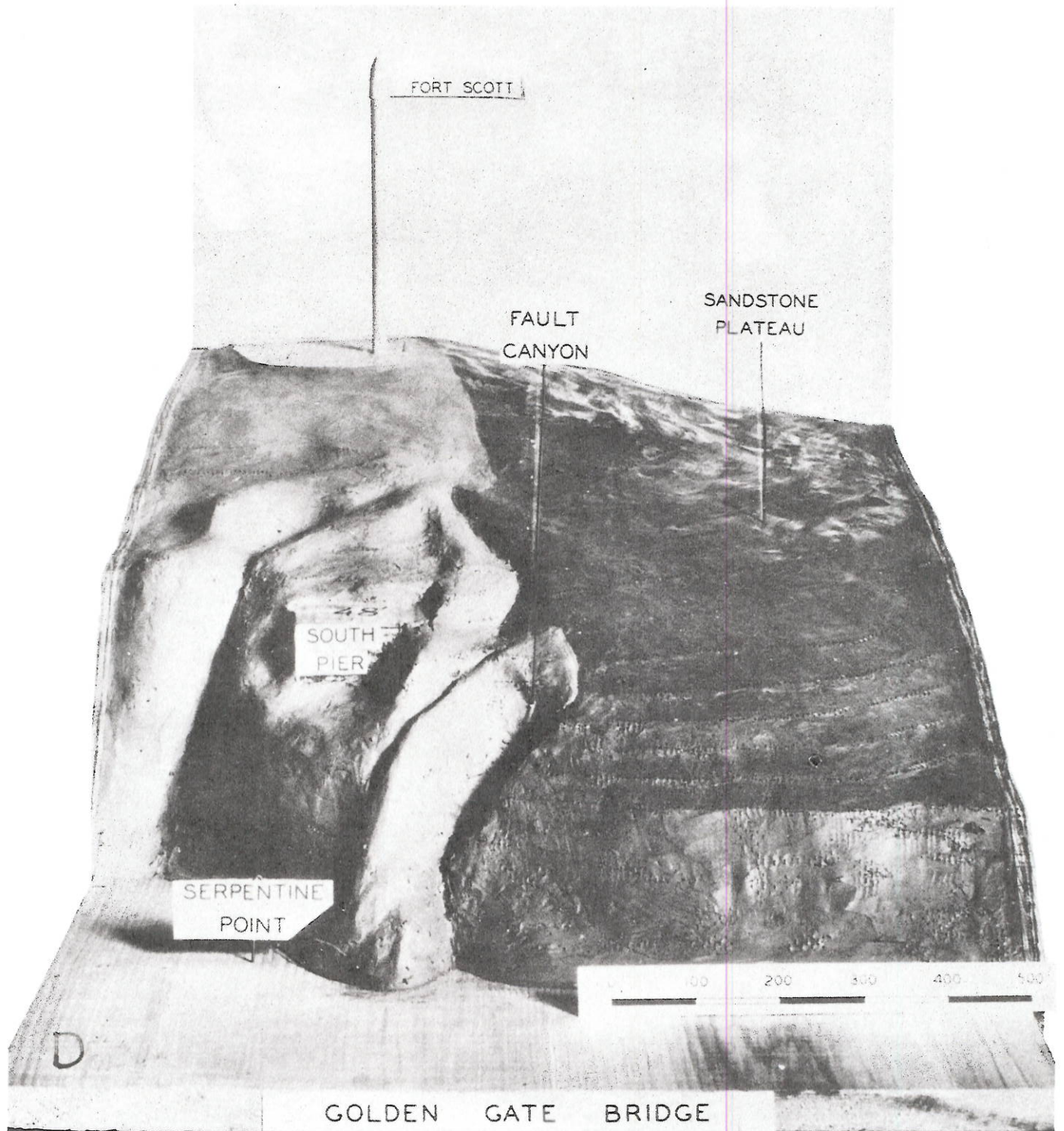


GOLDEN GATE BRIDGE
 SOUNDINGS IN FEET BELOW MEAN LOW WATER
 SAN FRANCISCO PIER SITE
 Scale: 1 inch = 20 feet.
 Jan. 26, 1934.

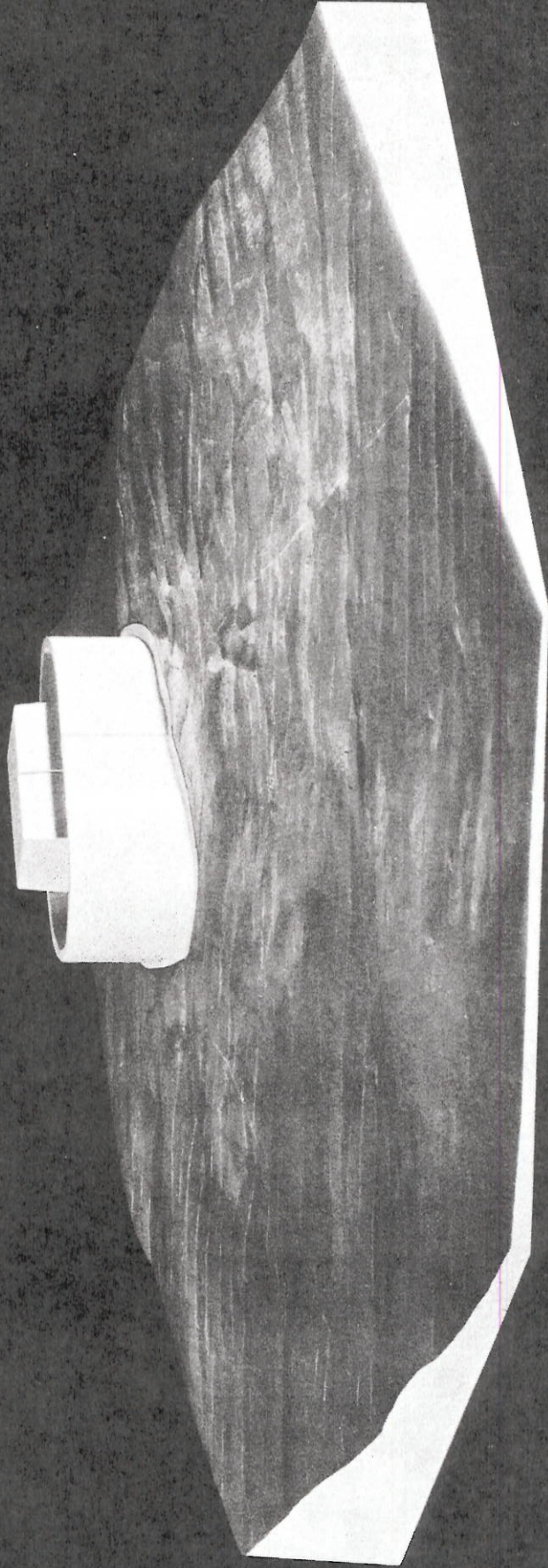
Prepared By
 JOSEPH B. STRAUSS
 CHIEF ENGINEER
 SAN FRANCISCO, CALIF.

38" x 45"
 5-2003
 ER-1



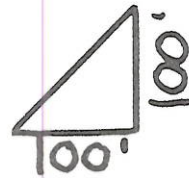


THIS MODEL, BY PROFESSOR WILLIS, IS ON A DISTORTED SCALE. ANY SOUNDINGS USED IN ITS MAKING WERE TAKEN FROM COAST AND GEODETIC CHARTS. FROM SUCH SOUNDINGS IT IS IMPOSSIBLE TO DERIVE SUCH DETAIL AS SHOWN HERE.

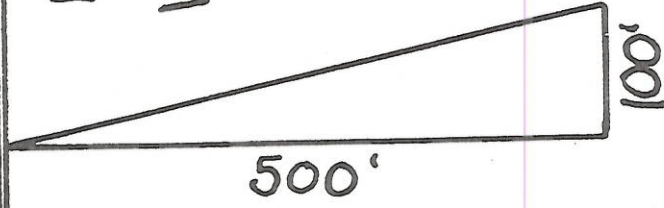


THIS MODEL IS AN EXACT REPRODUCTION ON A NATURAL SCALE OF THE SAN FRANCISCO PIER AND FENDER AND ROCK SURFACE UPON WHICH THEY ARE BASED. PIER AND FENDER MADE FROM CONTRACT PLANS. THE RELIEF MAP FROM THE 600 SOUNDINGS TAKEN BY DISTRICT FORCES.

NATURAL SCALE
USED FOR DISTRICT
MODEL OF SITE



EXAGGERATED SCALE
USED FOR
WILLIS MODEL



We have referred to the publication of the article in the Argonaut and the errors therein. Subsequent to the publication of that article in the Argonaut, cuttings thereof were transmitted by Professor Willis to geologists and others throughout the United States under date of October 19, 1934, which letter is as follows:

"The San Francisco Argonaut, of which copy is sent you at my request, contains an article relating to a difference of opinion between Professor A. C. Lawson and myself.

"The issue involves the stability of the greatest bridge ever planned. I am urging the appointment of an impartial Federal Commission to investigate and determine the facts.

"If that course appears to you desirable, a letter addressed to the Chairman Building Committee, Golden Gate Bridge, Mr. Francis V. Keesling, 690 Market Street, San Francisco, would aid toward a sound solution.

Sincerely yours,

(signed) Bailey Willis"

This, of course, initiated considerable correspondence. It is not necessary to comment on the impressions which were created by an article which is misleading but which is bound to be accepted as accurate, issuing from one man of professional standing to another.

In the Stanford Daily, October 22, 1934, Professor Willis was quoted as follows:

"It is my opinion, however, that the decision will rest with the public, since only failure to sell the bridge bonds appears to be likely to force those who are most interested in building the bridge according to the present plans, to apply for a federal commission." (Transcript 3, page 3.)

It was suggested to the Professor that he convicted the Board of Directors of antagonism prior to any consideration of this problem by the Board. He then apologized to the Committee in so far as there seemed to be any reflection on them. (Transcript 3, page 4.) As indicative of the results, there appeared in the Palo Alto Times of November 8, 1934, an editorial entitled "What a Peculiar Board." Believing that the public should not be misled, the Chairman addressed a communication dated November 15, 1934, to the editor, stating:

"My long and varied experience warrants the belief that editors as a rule desire to be fair. I can only surmise whence came the information upon which that editorial was based because so far the committee which is conducting hearings in an earnest desire to determine the facts has issued no statement except by way of progress."

The letter included the portion of the transcript relating to the article in the Stanford Daily just alluded to and in which Professor Willis had at the hearing on October 30th apologized to the committee and the portion of the record in which Professor Willis states:

"I want to thank you, Mr. Chairman, for your courtesy throughout the hearing."

and informed the editor that Professor Willis had experienced treatment equal to that which should be accorded him in the presence of any tribunal which has power to punish for contempt.

Professor Lawson, who attended all the hearings, and Professor Sedgwick, who was called in for conference and to examine the record, prepared and submitted a joint report dated November 13th. Only the conclusions will be noted, as the report of the geologists has been referred to in the early part of this report:

"In conclusion, we desire to assure your Honorable Board that there is nothing in any of the numerous and discordant statements made by Professor Willis since April 7, 1934, which would lead us to modify our original opinion as to the stability and integrity of the rock foundation upon which you are at present building the south pier.

"Every statement, which, if left unchallenged, might alarm the general public regarding the safety of the bridge, has been carefully scrutinized, checked up in the files, analyzed and found erroneous as to the fact or inference, and we reiterate that the foundation of the south pier is competent to carry the static load imposed upon it by the bridge."

It was developed in the course of the hearing that Professor Willis did not know that the District had had the benefit of the services of a geologist other than Professor Lawson, and he has asserted that it is hazardous to rely on the opinion of one man, that there is a difference of opinion between him and Professor Lawson and that for that reason the District should have other advice. (Transcript 1, pp. 20-21.)

In the opinion of the Committee, Professor Willis has not established the existence of the sandstone which he alleges to extend north and west of the pier and to slope under the pier, nor that the structure is faulted between the overlying serpentine and the alleged sandstone, nor that there is any condition of the structure other than that which has been known to the geologists and engineers and upon which the location and design of the south pier have been predicated.

Professor Willis' original objection to the foundation is stated in these words:

"The southern anchorage and the south pier are founded upon a

mass of sheared rock involved in a system of minor faults and consequently unstable to a degree likely to endanger the structure. The rock is serpentine and is subject to landslides, as can be seen in the immediate vicinity. Slides have occurred under natural conditions." (See Page 6 hereof.)

He then developed the underlying sandstone theory.

The excavations for the anchorage definitely established that at that point the serpentine is neither faulted nor sheared. Professor Willis has not established any sliding except where it has been due to wave action only possible on the shoreline. In other words, it is the pounding action of the sea which wears away the bases of any kind of rock.

With reference to the existence of the alleged sandstone sloping under the serpentine upon which the south pier rests, it was determined to be in the public interest, and, therefore, the duty of the directors not to rely entirely upon the conclusions of the Building Committee and the opinions of the geologists and engineers. To determine the existence of any sandstone under the pier a hole was drilled into the foundation at the west end thereof, immediately inside the base of the fender wall on the east-west axis of the pier. This location was selected because of Professor Willis' claim that the alleged sandstone sloped downward from west to east under the pier, and, according to his projection which appeared in the "Argonaut", it should be developed within approximately thirty feet below the excavation for the pier at the west end.

The drilling proceeded to a depth of 251.62 feet below sea level and 159.37 feet below the base of the pier. Professor Lawson reports:

"The cores recovered show that the hole for the entire 159.37 feet passes through serpentine and through nothing else. To the limit of the depth reached there is no sandstone and no fault. The information yielded by this drilling effectively and completely negatives the statements which Professor Willis has published so widely, so persistently, and so maliciously.

"The average recovery of cores from the drill hole is 57.5 per cent, which is a good percentage. * * *

"Since the sole purpose of drilling this bore hole was to test the truth of Professor Willis' assertions, and since these assertions have been proven to be wholly untrue, it is in my opinion unnecessary to do any further drilling into the foundation rock of the south pier."

Serpentine in its natural state is not a sliding mass and it has been demonstrated by excavations on shore and for the south pier and drilling at the south pier site that there is no faulting nor shearing as alleged by Professor Willis.

Professor Willis is meticulous where the accuracy of statement is involved. We therefore do not quote except from the record, to avoid the controversy that would certainly ensue, no matter what the recollection of all others as to the purpose of statement. However, the record discloses inaccuracy where accuracy is demanded of a man of science. We refer to the error of 100 feet in the depth of the water in the east-west section, which was published in the "Argonaut" and the exaggerated slope hereinbefore referred to. The exaggerated slope without doubt is understood by the scientific mind but it certainly made a very definite impression of danger on the layman. The fact that the exaggeration of slope on the model was noted thereon by Professor Willis could not possibly overcome the ocular effect on the lay mind created by the exaggerated slope. Not only was there the error of 100 feet in the depth of the water depicted in the section published in the "Argonaut" but the drawing of the heavy foundation and the tower of the proportions delineated resting on a thin layer of serpentine superimposing a sloping sandstone, was designed to create, and had the effect of creating in the lay mind the impression that a slide was not only possible but extremely probable.

It has been reported that Professor Willis claims that the line indicating the fault between the sandstone and the serpentine in this same section is a broken line which means to the geologist that the depth of the sandstone is unknown. The fact is that the line is not broken. It is also a fact that the broken line would be meaningless to the lay mind. That section was intended for the lay reader. The Professor was not promulgating a monograph for scientists.

Professor Willis was inaccurate in locating the pier and he did not avail himself of the facts which were accessible, and his reasons for not doing so are mere pretext. It was his duty as a man of science, contemplating a report of the type which he transmitted to Washington, to investigate all the facts. This he did not do.

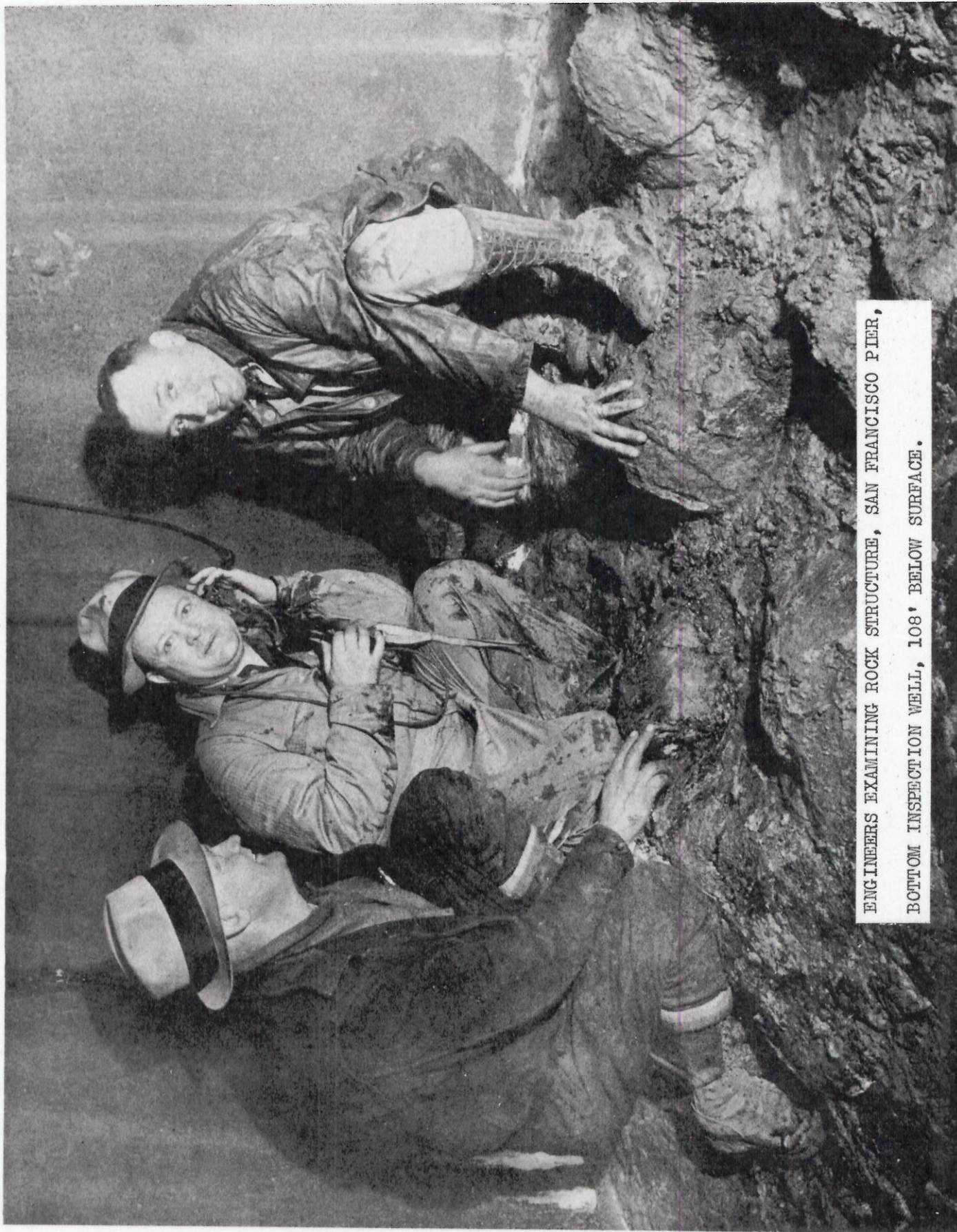
The conclusions of your Committee are not based upon what may be the misconduct of Professor Willis but are based upon the facts. Professor Willis has not substantiated his conclusions.

The Committee is satisfied that the serpentine structure is sufficient and that there is no sandstone within any range which should concern the Board of Directors.

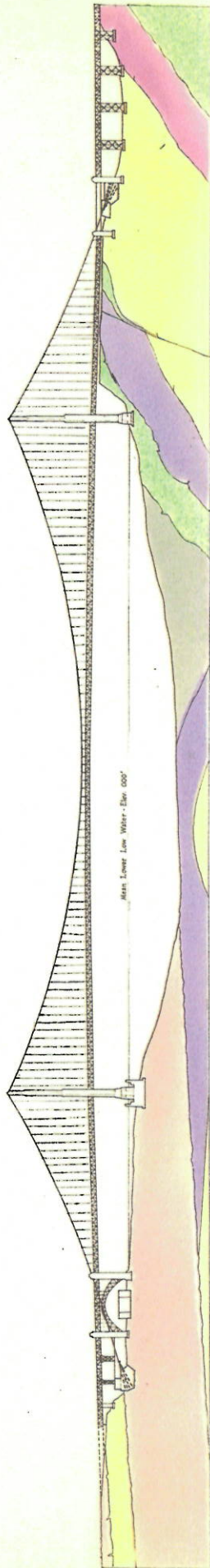
The Committee recommends, therefore, that the Board of Directors disregard the recommendation of Professor Willis.

Respectfully submitted,

(Sgd.) Harry Lutgens
(Sgd.) Thomas Maxwell
(Sgd.) F. V. Keesling,
Chairman, Building
Committee.



ENGINEERS EXAMINING ROCK STRUCTURE, SAN FRANCISCO PIER,
BOTTOM INSPECTION WELL, 108' BELOW SURFACE.



**GEOLOGICAL SECTION
ACROSS THE GOLDEN GATE**
On the Center Line of the
GOLDEN GATE BRIDGE
By Andrew C. Lawson

Scale
0 200 400 600 800 1000 ft.

SUSAULTO
CHERT

MARIN
SANDSTONE

INGLESIDE
CHERT

BONITA
SANDSTONE

DIABASE
& BASALT

SERPENTINE