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EARTHFLOWS AT THE BEATTIE MINE - A CASE RECORD

by

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PREFACE

The constructive study of failures is an essential part of research work. Such investigations are of special value in the field of soil mechanics since there is still so much to be done in the correlation of laboratory tests of soil samples and the performance of soils *in situ*.

This report is a progress statement of such a study to which the writer had long looked forward. He was consulted about this failure by Mr. F. E. Lathe even before the Division of Building Research was formed and had kept in mind the value to be derived from a study of the unusual slides at the Beattie Mine.

Accordingly, it was a pleasure to arrange for the author of this report, who is a research officer in the Soil Mechanics Section of DBR, to visit the Beattie Mine with an associate for a preliminary study in the field of the earth failures. This report represents a summary of information then obtained and all the subsequent laboratory investigations. The assistance of the mine authorities in this study was greatly appreciated and in particular the interest of Mr. W. R. Salter, President, Beattie Duquesne Mines Limited.

As soon as staff are available, further studies will be carried out as suggested in the body of the report. A complete paper on the project will then be prepared and published if the necessary authority for this can be granted, the intention of both this report and any subsequent paper being to make available to the engineering profession significant information which will assist with further earth works of the type involved.

Ottawa
May 1961

R. F. Legget,
Director.

EARTHFLOWS AT THE BEATTIE MINE - A CASE RECORD

by

W. J. Eden

In June 1943, an earthflow involving 1,000,000 cubic yards occurred at the Beattie Mine, Duparquet, P.Q., filling the open pit and underground workings at the mine. Attempts were made to rehabilitate the mine, but these were frustrated by other large earth flows in 1945 and 1946. These notes outline the sequence of events leading up to the earthflows, describe the earthflows, and give the results of a two-day field study undertaken in May 1960.

History of the Mine

The Beattie Mine began production in 1933, the gold-bearing ore being won from a large relatively low-grade ore body. The ore body lay along the north flank of a rock ridge oriented in an east-west direction. At the west end, the ore body came to surface and plunged under overburden towards the east. Ore was mined by a combination of "glory hole" and underground stoping methods. Tuttle (1939) gives a detailed description of the workings. The "glory hole" was an open pit with very steep sides and sloping ends. The hanging wall of pit was supported by the footwall by means of four pillars left across the pit at frequent intervals. The ends of the pit sloped at about 40 degrees. Ore was mined from the ends of the pit and rolled down the slopes into the underground system. By 1943, the "glory hole" was about 1,000 ft in length, about 40 ft wide at the east end and over 200 ft wide at the west end. The deepest point of the pit was about 300 ft below the surface.

The production at the mine was scheduled so that the glory hole or pit was worked during the summer months; the more expensive underground development and mining were conducted during the winter.

As production proceeded, the pit was gradually lengthened, requiring the stripping of greater and greater depths of overburden from the east end and north side of the pit. In its early stages, the stripping was accomplished by horse and scrappers. As the amounts of stripping grew larger a tower dragline system and mechanical equipment were used.

In all cases, the stripped material was deposited near the top of slopes cut in the overburden. The slopes were cut to a slope of 4:1 with a berm bordering the ore body. The maximum depth of overburden was about 100 ft, consisting of 85 ft of clay underlain by 15 ft of sand. Figure 1 is a photograph showing the slopes in 1943. The overburden consisted of varved clay overlying a few feet of sand over the bedrock. The varved clay was deposited in late glacial times in Lake Barlow-Ojibway (Antevs 1925) and was found to be nearly normally consolidated. The mine was located about one mile north of Lake Duparquet and the rim of the pit on the west end was about 60 ft below the lake level. Seismic surveys showed there was no ledge of bedrock between the rim of the pit and the shores of the lake. The tailings disposal site was located in swampy land near the southwest corner of the pit. It was noted that considerable seepage issued from the sand underlying the clay, particularly at the west end of the pit, closest to the lake shore, and the tailings disposal area.

Earthflows

By the nature of the stripping operations, a slope failure could be expected. The magnitude of the eventual failure, however, is somewhat surprising in view of the varved clays being fresh water deposits. The first slide recorded in the available records was on 19 June 1937. It occurred at the northeast corner of the glory hole, had the characteristic shape of an earthflow, and involved a few thousand yards of material.

The second slide recorded, in 1942, was about midway along the north side of the glory hole. Again, this slide did not seriously affect operations in the mine.

In June, 1943, a tremendous earthflow occurred which involved a million cubic yards of clay. This slide completely filled the glory hole and penetrated the underground workings. Some clay ran nearly half a mile along the sixth level drift towards the Donchester Mine which was connected to the Beattie Mine underground. The main pillar supporting the hanging wall of the pit collapsed, allowing the hanging wall at the east end of the pit to fall into the pit. According to information received from Mr. F.E. Patton in correspondence, the main pillar collapsed during the night of 15-16 June, 1943, prior to the soil movement. The extent of this landslide is shown in Figure 2, along with the smaller failures recorded in 1937 and 1942. Figure 3 is a photograph taken from the west end of the glory hole on 16 June, 1943, showing part of the earthflow.

While the neighbouring Donchester mine remained in operation, steps were taken to rehabilitate the Beattie Mine. In the underground workings, the clay was sluiced by high pressure water jets and the resulting slurry was pumped to the surface. Small hydraulic dredges were set up in the glory hole and in the slide crater to remove the clay from the pit area. By June 1946, about $1\frac{1}{2}$ million cubic yards of clay had been removed from the pit area and the underground workings. It was estimated that a further one million cubic yards had to be removed before any production could start in the mine.

In 1945, a few small slides occurred in the crater, undoing some of the work of the dredges. The slides continued in 1946, the largest one occurring on 25 June, involving about 250,000 cubic yards. Figure 4 is a panorama view from the west end of the mine taken in July 1946. Slides continued throughout the summer, the last ones recorded being on 13 and 28 September. As Figure 2 shows, these slides occurred towards the west end of the pit. In the fall of 1946, gold market prices were falling, and so far as is known, all serious efforts to rehabilitate the mine ceased, except for the sinking of a shallow shaft to reach a lode of rich ore at the west end of the pit.

Field Investigation

In May 1960, a three-day visit was paid to the Beattie property to obtain more information on the soil properties. Figure 5 shows the site conditions in 1960. The lake shown occupies the crater formed by the earthflows. The footwall of the glory hole appears at the right of the picture. The rock point jutting out at the lake water is the top of the former hanging wall of the pit. The photograph looks in the northeast direction. The site chosen for sampling was along the north shore of the crater slightly left of centre of the photograph.

It was found that the walls of the crater were formed of varved clay. A retrogressive type of failure was indicated by the slump blocks which could be observed around the crater. During the sampling work, layers of sand or silt were encountered in the varved clay. With the hand equipment, it was not possible to penetrate the sandy layers, so that the profile of samples obtained were taken in three borings spaced down the face of the crater. From the three borings, a profile of samples representing 30 ft of varved clay was obtained. The sampler used was the NGI piston sampler (Bjerrum 1954). It is believed that the bottom of the failure surface was 10 or 15 ft below the bottom sample, so that the results obtained cannot be applied to a stability analysis. It is hoped, however, that a general impression of geotechnical properties of the varved clay of the site may be gained.

Elevations of the borings were taken in relation to the collar of development shaft located at the west end of the glory hole. From the mine records, it is inferred that the elevation of the clay plain was about 930. Thus the level of the water in the crater in May 1960 was about elevation 900. No precise bench mark could be found in the mine records to serve as a datum for the field investigation.

Laboratory Work

The nine tube samples were tested to determine the undrained strength, the preconsolidation pressure, and classification properties. Whenever it was possible, classification and sensitivity tests were performed on separated samples of dark and light layers of the varved clay.

The results of tests are presented in Figure 6; line A-A is the effective overburden pressure, taking the surface of the clay to be about elevation 930 with the water table close to the surface. The results of the consolidation tests indicate that the clay is slightly overconsolidated and indicates that a drying crust has developed at the surface. The undrained strength determinations made indicate that the undrained shear strength was about 500 psf, increasing slightly with depth.

Classification test results are presented in the form of solid lines for tests conducted on mixed light and dark layers of the clay and by broken lines for these tests conducted on samples made up of separated dark and light layers. It will be noted that difference in properties between the dark and light layers was great.

Sensitivity was determined for the mixed samples by means of a laboratory vane apparatus and are plotted on Figure 6. An attempt was made to determine the sensitivity of the individual layers of dark and light material by means of a fall cone device. These results are tabled in Figure 6 and indicate that the light layers were generally more sensitive than the dark layers. The over-all sensitivity appears to be above 15 which is unusual for fresh water clays in view of the findings of Skempton and Northey (1952) and Bjerrum and

Rosenqvist (1956).

To indicate the variation in properties between the dark and light layers, Figure 7 presents the profile of sample No. 99-5 along with the variation in natural water content. The variation in water content between the dark and light layers is similar to that found for the varved clays at Steep Rock (Eden 1955).

Figure 8 is a Casagrande classification chart showing the Atterberg determinations on the separate laminae of the varved clay from the Beattie Mine, along with results from other sites (Milligan 1960). It can be seen that the Beattie Mine clay is comparable to varved clays from other sites in Northern Ontario.

Undrained strength determinations were made by three methods: the laboratory vane, the unconfined compression test and the unconsolidated, undrained triaxial test with lateral pressure approximately equal to the effective overburden stress. The results of the three test methods are presented and in general appear to have given comparable results. If the laboratory vane tests appear to be slightly lower, it is because the vane determinations were made on the first specimen extracted from each tube and hence the tests were conducted on specimens which may have suffered more disturbance than the remaining samples.

In the unconfined compression tests on specimens with the varving nearly horizontal, failure occurred by spreading in the light layers and vertical cracks in the more brittle dark layers, similar to that reported for the Steep Rock clays (Eden 1955).

Conclusions

1. This investigation has shown that the varved clay at the Beattie Mine is nearly normally consolidated and very sensitive. A shallow drying crust appears to have developed at the surface. In the 30 ft of clay investigated, the undrained shear strength was found to be about 500 psf, showing a very slight increase in strength with depth.

There was considerable difference in properties between the light and dark layers of the clay comparable to that found for other sites in varved clay. The light layers appear to be slightly more sensitive than the dark layers.

2. It is believed that the failure was primarily due to

the method of stripping, and not to seepage pressures in the underlying sand although the seepage pressures may have contributed somewhat to over-all instability. By the process of gradually deepening the excavation and piling the spoil on top of the slope, a failure was inevitable whether or not there was high water pressure in the sand. The important feature of the failure was the liquefaction that occurred in disturbed material, indicating that varved clays are prone to the flow type of landslide.

3. Because of the lack of precise information on the dimensions of the slope and the lack of deeper samples, only a very crude stability analysis was attempted. By Taylor's method (1937) a shear strength of about 700 psf is required for 80 ft slope cut at 4.1 in clay. The Beattie Mine failure in fact is a full-scale shear strength test on varved clay, and the writer would suggest that further work is to be commended. As a first step, with the co-operation of Beattie Duquesne Mines Limited, the present owners, a thorough search should be made of the mine records at Duparquet to obtain more precise information on the dimensions of the slopes. Secondly, responsible officials of the mine at the time of the failure should be interviewed in an effort to obtain a clearer picture of the sequence of events. Thirdly, samples should be obtained throughout the clay profile. This will mean equipment capable of driving a cased boring to a depth of 100 ft or more. From the writer's experience, the presence of sandy silt seems to make an uncased hole with light hand equipment impracticable.

Acknowledgments

The writer would like to acknowledge the assistance given by A.O. Guibord and K. Timmins of the Soil Mechanics Section, Division of Building Research, in the field work and J.B. Bordeleau and D. MacMillan who conducted most of the testing. Mr. Gilhuly of Beattie Duquesne Mines Limited, Duparquet, was most helpful at the site in giving access to the property and looking out the mine records.

Much of the information on the sequence of events during the landslides were obtained from the files of the late Dr. F.E. Lathe, of the Technical Information Service, Department of Reconstruction and Supply (now part of the National Research Council). Special acknowledgment is due to Mr. F.E. Patton, of Kitchener, Ontario, who was chief engineer, later manager, at the Beattie Mine in 1934 to 1957. He kindly supplied photographs and other information on the mine.

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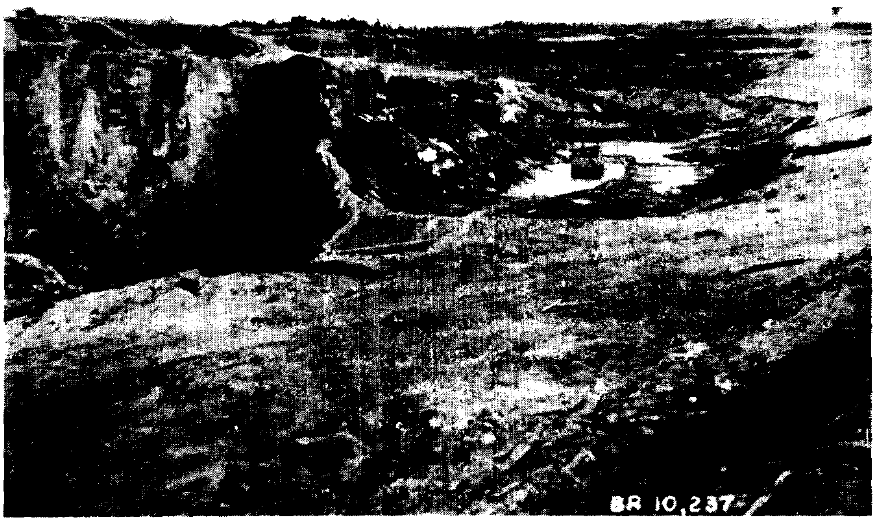


Figure 1: Clay slopes at northwest side of Beattie Mine - June 15, 1943.

(Photograph courtesy of Mr. F.E. Patton)

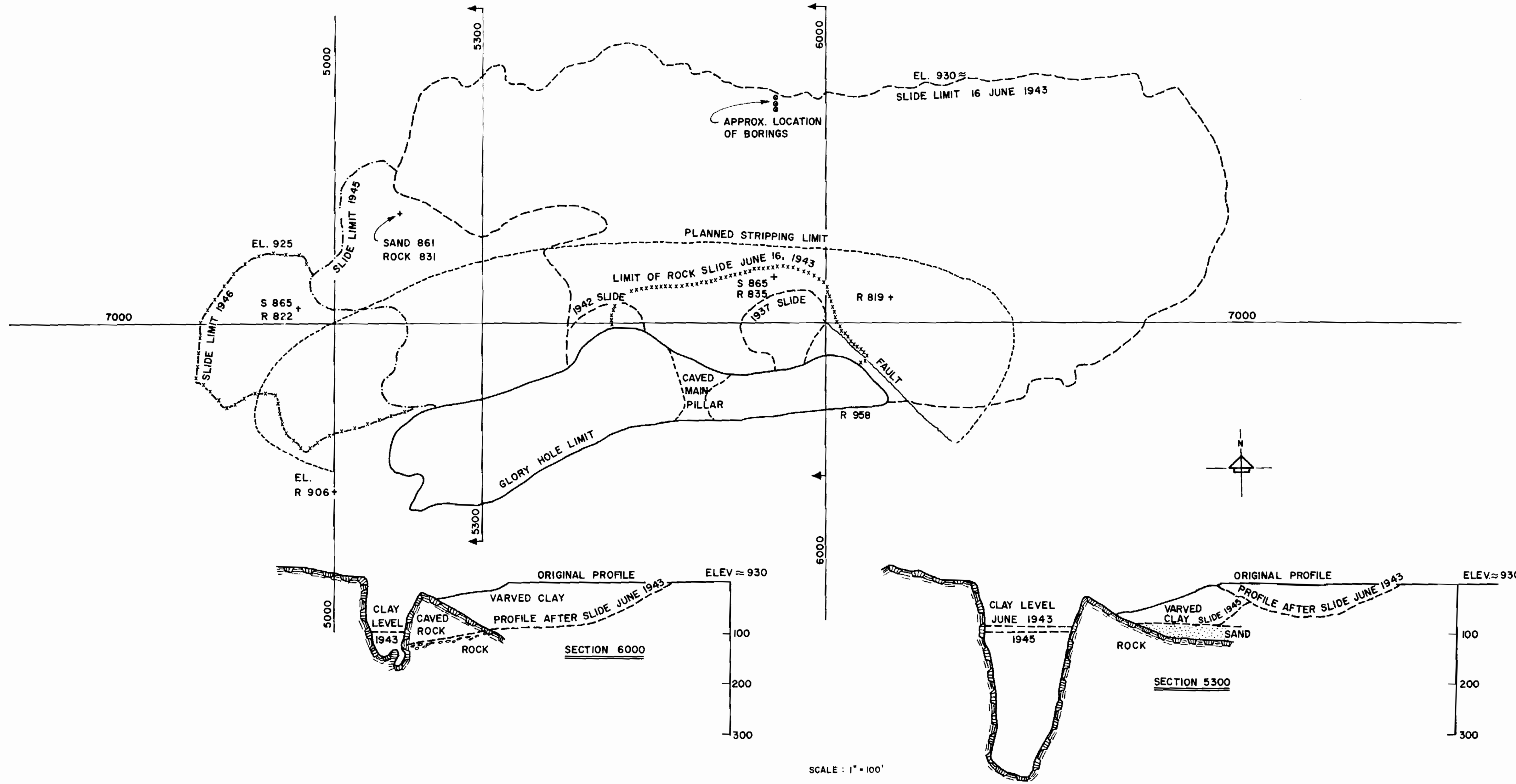


FIGURE 2 PLAN AND PROFILES OF LANDSLIDES-BEATTIE MINE

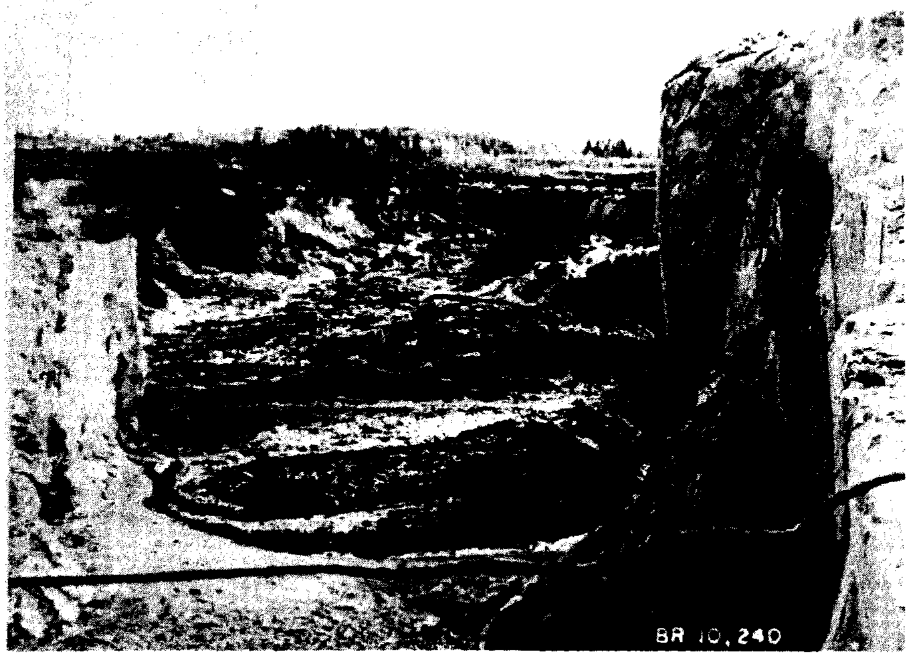


Figure 3: View from west end of pit after landslide of June 16, 1943.

(Photograph courtesy of Mr. F.E. Patton)

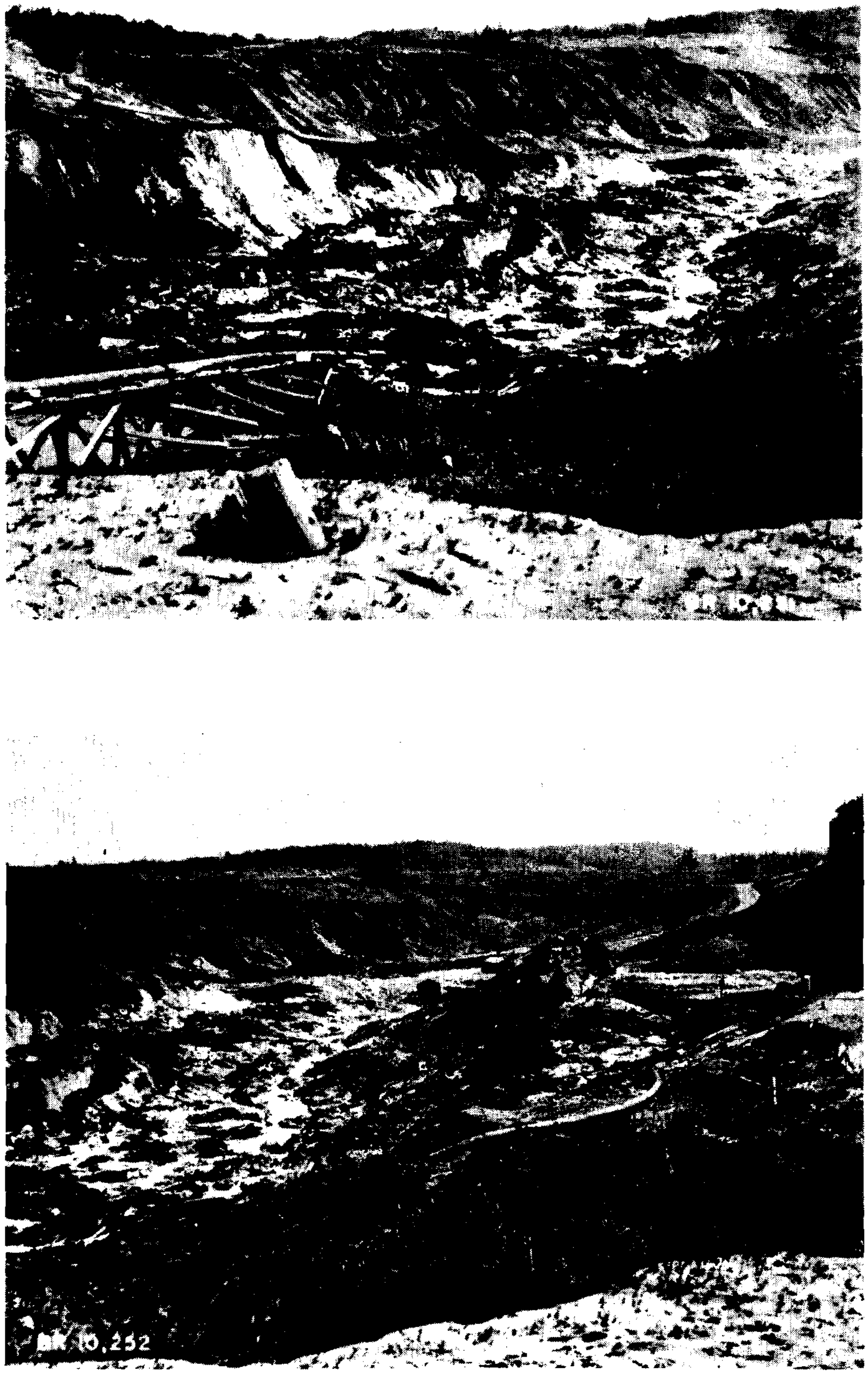


Figure 4: Panoramic view taken from west end of pit showing earthflows in 1945.

(Photograph courtesy of Mr. F.E. Patton)

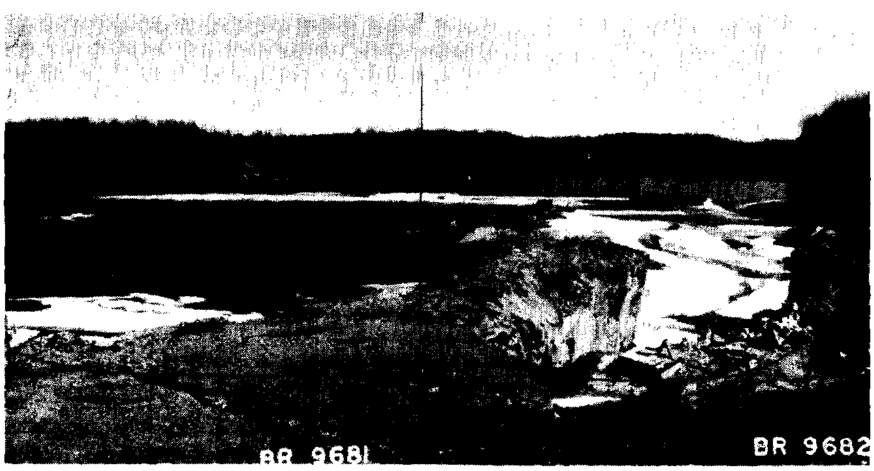
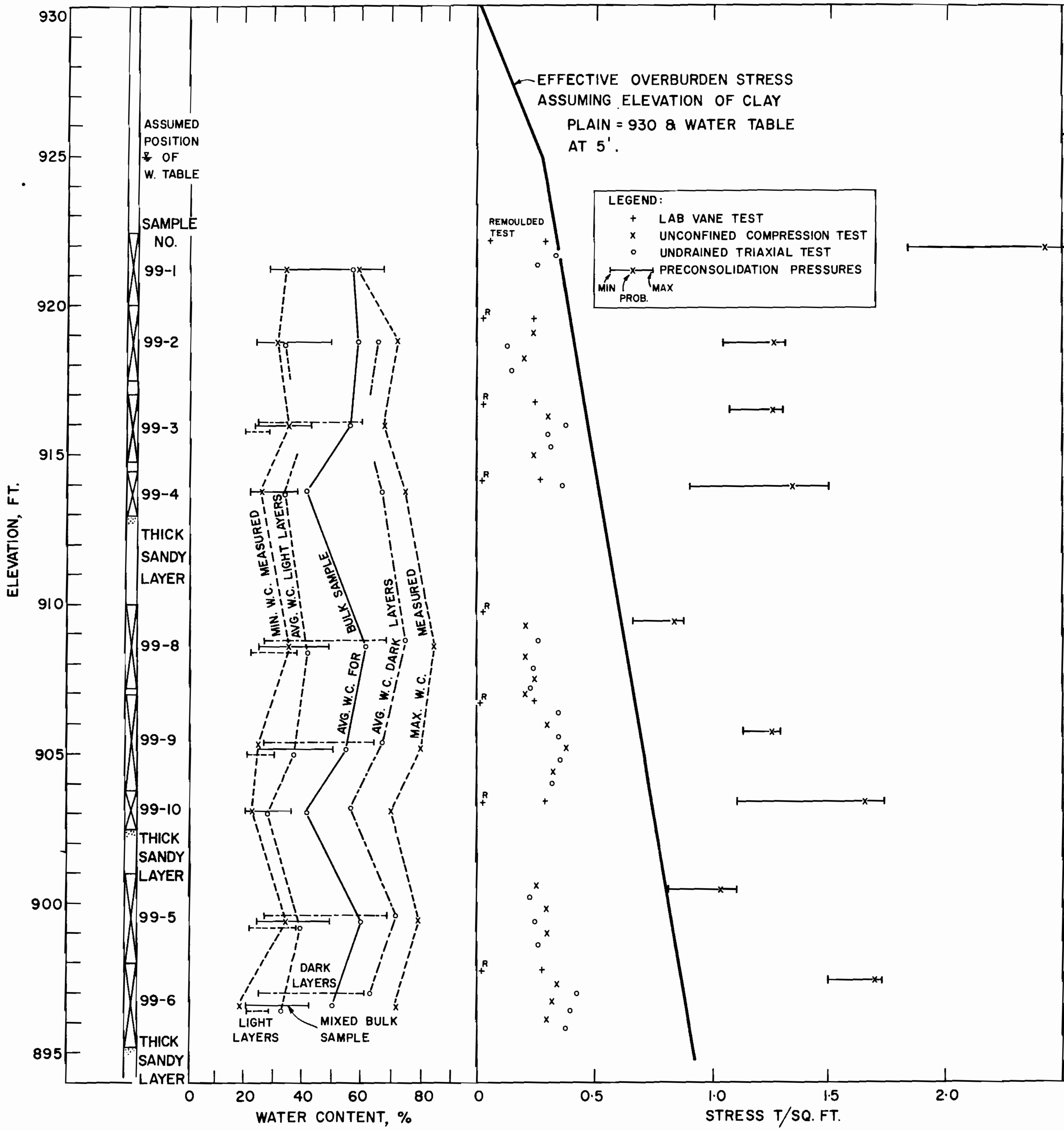


Figure 5: Panoramic view from west end of pit showing present site conditions - May 1960.



ST BULK SAMPLE	ST LIGHT LAYERS	ST DARK LAYERS	% CLAY BULK SAMPLES	L.I. BULK SAMPLES	L.I. LIGHT LAYERS	L.I. DARK LAYERS
6			87	0·73		
14	25	15	76	1·36		
13	30	24	60	1·66		
16	27	15	57	1·05		
	15	18	78	1·57	1·19	1·15
19	33	20	66	1·17	1·68	1·06
12			50	1·28		
	22	18	74	1·41	1·64	1·07
14	20	18	46	1·33	1·46	1·04

FIGURE 6 COMPOSITE BORING LOG SHOWING TEST RESULTS - BEATTIE MINE

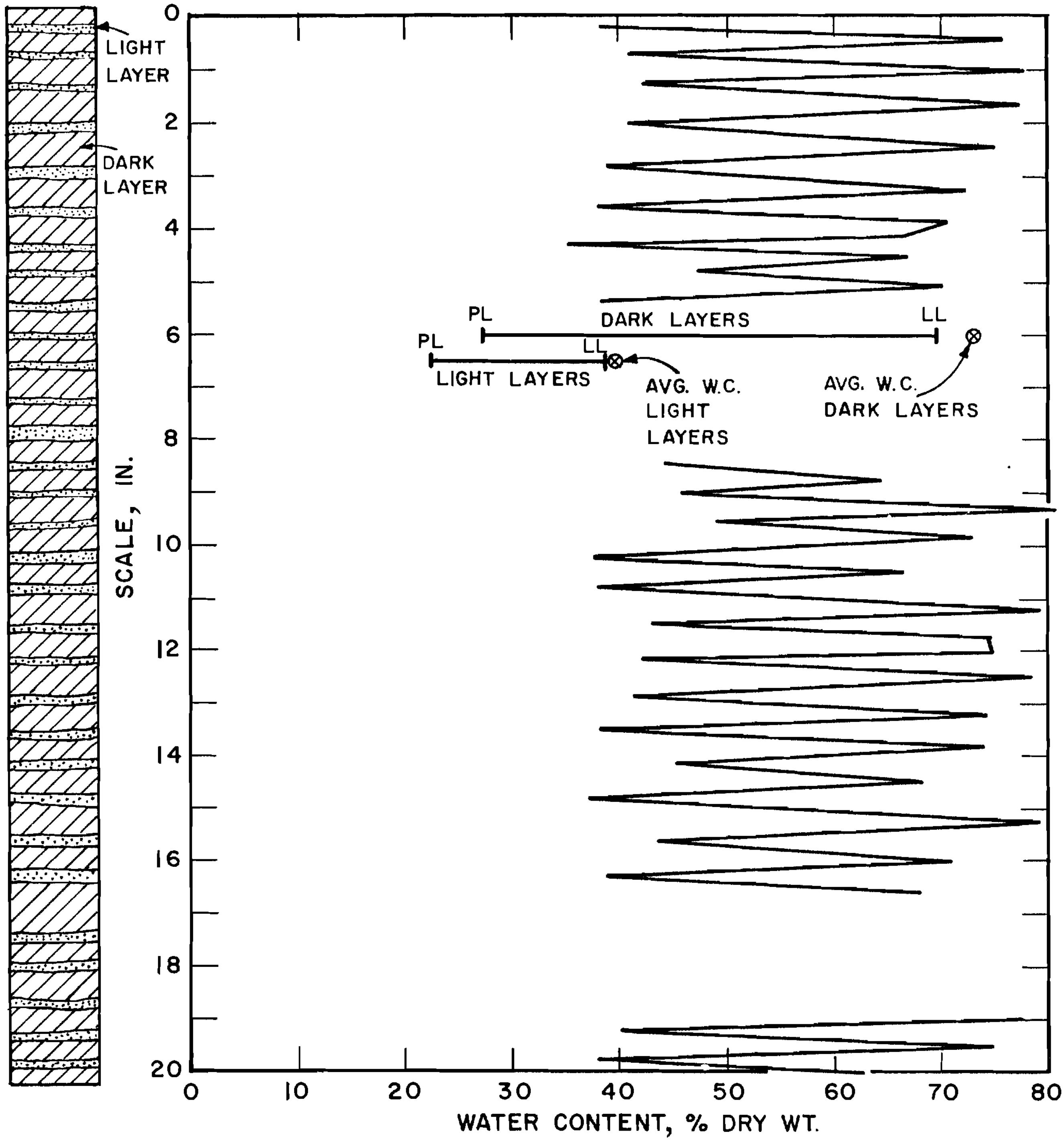


FIGURE 7
VARIATION IN WATER CONTENT FOR SAMPLE 99-5 VARVED CLAY-BEATTIE MINE

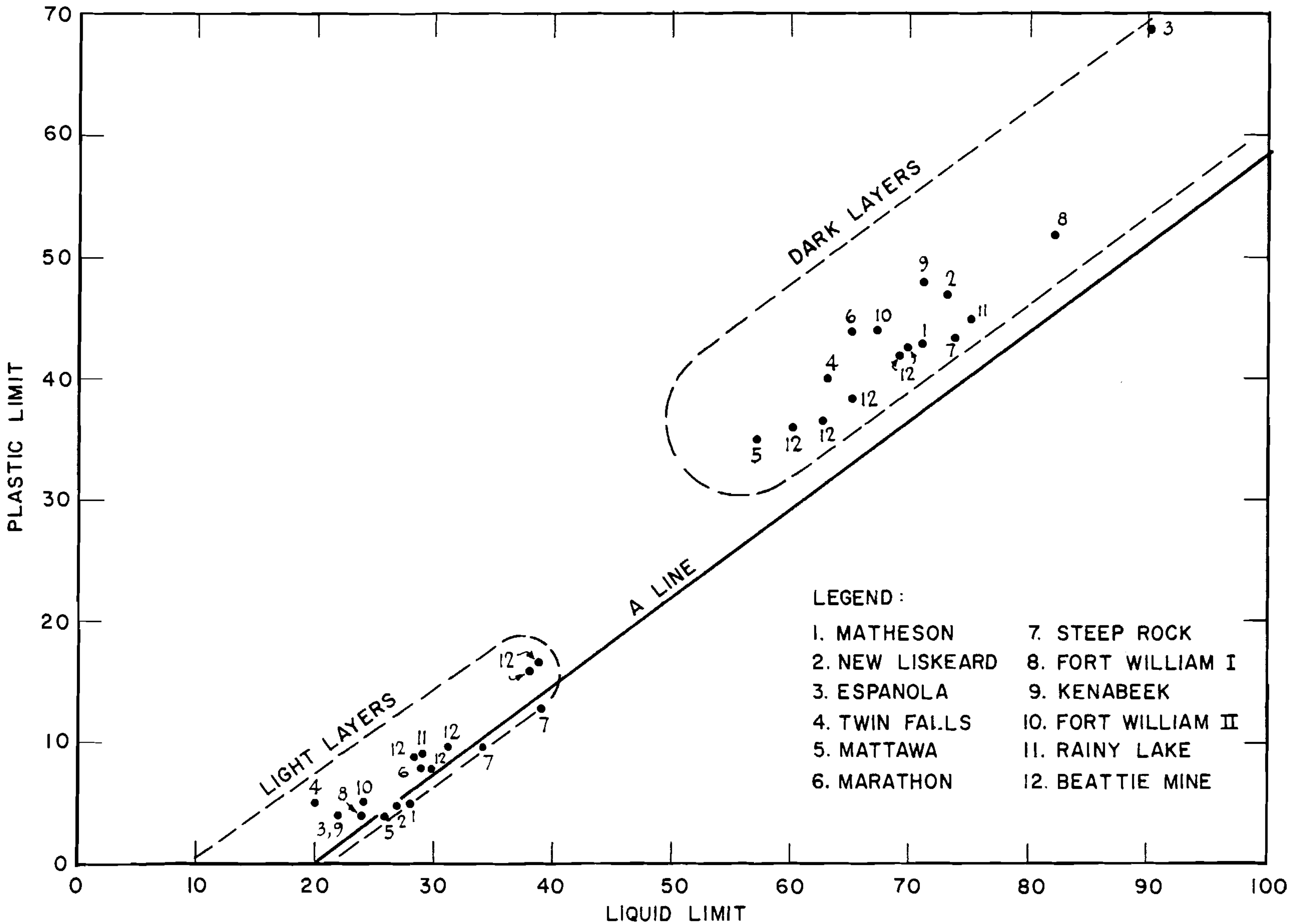


FIGURE 8
CASAGRANDE CLASSIFICATION CHART FOR VARVED CLAY (AFTER MILLIGAN)

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