Slope failures in the Lavender pit
Bisbee, Arizona

(Draft Version)

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Written 1970-1972

CONTENTS

ILLUSTRATIONS

Abstract.

Two major slope failures have occurred in this open pit recently, both are interesting in that they are related to pre-pit mining by underground methods and waste dumping of an earlier pit. The slide on the east wall of the pit damaged or destroyed many company buildings including a diesel generating station, a compressor station, a hoist house, and has damaged several non-company structures, causing a substantial decrease in ore reserves. The second slide is on the southwestern wall of the pit and, at present, has caused no damage, but is of such huge proportions (24 million cubic yards) that it is a matter of concern. Both slides are being extensively monitered and corrective measures have been initiated.

INTRODUCTION

Pit slope failures are unfortunately a common occurrence in Arizona open pit copper mines. Slides range in size from an occasional boulder to those involving millions of tons. They may be differentiated by their effect on a mine as a failure or as an operational failure. The former being displacement without damage or expense, and the latter being one of damage or mining limitations accompanying the displacement. One of each type has been studied here. The example of a failure is called the south slide. The operational failure is called the east slide.

GEOLOGY

A series of intrusions by granite porphyrys and breccias along an ancient structure have invaded thick bedded Paleozoic limestone, resulting in the formation of one of the world's richest mining district. During Jurassic times, uplift along ~~the~~ faults resulted in removal by erosion of any ore deposits to the north of the fault. During the Cretaceous period, a sandy conglomerate was deposited over the area, burying much of the ore. This is true in the case of the east end of the pit when 300-350' of the conglomerate cover parts the intrusive stock.

The Paleozoic sediments, generally dipping to the southeast at 15-30 degrees, were a receptive host to the mineralizing fluids. Massive replacement by sulfide and much alteration, mostly by silicification, occurred in these sediments. Weathering has further enriched the ores, resulting in huge low grade ore bodies and smaller bodies of high grade oxide ores. Accompanying the ore bodies often times are large masses of impure hematite and limonite that have long presented support problems.

The structural features of the pit area are mainly strike slip and dip slip faults often exhibiting displacement of several thousand feet, while jointing is of minor importance. It is,in fact, the structures that play an important part in limiting the extent of the slide. Both the structure and general rock type are outlined in figure one.

HISTORY

Underground mining in the area

Underground mining which is still active today, has been carried on in the district for about 100 years, generating nearly 2,000 miles of workings. Two basic mining methods were used in the pit area; the first one, used in the south section between 1890-1910, is the cut and fill technique. With this technique a section of the ore body is mined and the void is filled with waste rock to aid in supporting the overburden. This method is very effective for short-term occupancy. The second method used during the 1920's and 1930's at the east end of what is now the pit, is block caving, a method in which the entire ore body is dissected and broken, collapsing the area above it. The ore is then removed from below until depleted, leaving a large, broken, and collapsing area which was not intended for future entry.

Previous pit

This district was one of the first where open pit mining methods were used. Begun in 1917, the older pit occupied an area central to the two slides. It was a rail operation that was worked until 1929 when diminishing copper prices and slides forced a cessation of mining. The position of this mine is indicated on figure one. The present pit was begun in 1950 without considering slope problems, even though subsidence had caused some surface problems in the conglomerate. An expansion in 1967 resulted in the inclusion of the ore area to the west and the south slide.

EAST SLIDE

Chronology

The east slide, on the east end of the pit, first exhibited movement in 1959 after the completion of the 4,600 foot level; however, it was not sufficient to cause concern. As mining proceeded and the pit was deepened, movement increased, but was partially masked by loose fill in the area. The slide continued to move until seventy-five million tons of broken rock had been displaced about 65 feet below its former level. Movement is still noted in the slide area; however, it is reacting favorably to corrective measures and appears to be stabilizing. A cross-section showing the relative altitude of the slope at different times is given in figure two.

Causes

The slide was restricted to the overlying conglomerate and broken porhyry as well as the residual material in the block caved area. The conglomerate is a red, sandy, pebble conglomerate of little or no relief in the district attesting to its inability to stand weathering.

Undoubtedly; however, the major cause was underground mining. A large area immediately below the slide in the porphyry had been mined by block caving. This resulted in a huge unsupported section, that was badly broken. The overlying rocks, in this case, the weak conglomerate, undoubtedly were cracked and broken by settlement, a feature that was not noted until the pit was in operation.

With the removal of the supporting toe by deepening the pit the last restraint was ~~gone~~ removed leaving no alternative other than mass movement. The restriction of the slide to block caved areas is sufficient reason to place the blame here.

Immediate effects

The first effects of this slide occurred within four months after movement began and worsened for the next year. The main hoist was the first affected and the ~~shafts~~ hoists froze due to differential settlement of the foundations. Soon after that, the two 5,000 C.F.M. compressors separated from their drive shafts with a corresponding forty percent loss in ventilation air ~~production~~ volume. The cooling tower for the powerhouse cracked and drained and had to be replaced.

Many cracks appeared in the adjacent community roads and in several brick structures. A U.S. highway suffered a slow displacement of several feet, and only a constant maintenance kept it open, until it was partially re-routed to avoid the potential danger. Before it was over the two remaining hoists for the mine were replaced by smaller more flexible units, the compressors were moved to a new locality at great expense, and floating foundations were put under the four diesel generators. The position of effected features is shown in figure three.

Long-term effects

The long-term effects of this slope failure are: (1) the danger presented to the highway, (2) the danger to the remaining mine structures, and (3) the possibility of renewed movement ~~of~~ within the community. This will require monitoring long after mining is terminated. The loss of substantial ore reserves, through the decreased slope angle and burial of ore by the toe of the slide have reduced the pit life by eliminating the last two levels of the planned mining.

Monitoring

Monitoring was done by the transit-stadia method, until the failure. With increasing danger to the community and mine property as well as continual mining in the bottom, it was evident that a continuous more sensitive monitor was required. One four inch (diameter) rotary drill hole was driven into the slide and an extensometer was inserted. A second was placed under the highway section. These instruments indicate ~~any~~ slope movement on gauges and trigger an alarm when an accleration takes place. The position of these is indicated on figure three.

Analysis of parameters

An adit was driven semi-parallel to the pit face for a total of 4,300 feet, with 9,000 feet of AX-BX drilling into both the slide area and the perimeter located the slide boundaries. A series of rock quality test holes were also drilled from the surface to investigate the rock underlying the highway and town.

The results were enlightening since the adit required little support and the drill holes indicated a boundary controlled by previous underground mining with no appreciable rock deterioration beyond its limits. Nearby, a major shaft suffered no adverse effects, and the rock surrounding it is surprisingly intact. The highway area, though broken appears to be stable, and the broken rock ends at a fault.

Corrective measures

Before mining was resumed at the pit bottom, much of the head was removed and dumped down the slide to decrease the angle of the slope and to build up the toe. This action appears to have been successful, since no appreciable displacement has occurred and no headwall cracks have appeared around the new pit limit.

Conclusions

The east slide was caused by broken ground left unsupported during underground block cave mining. The resulting slide could have been avoided only by an extensive investigation and overburden removal program prior to pit deepening.

SOUTH SLIDE

Chronology

Movement was first noticed when cracks appeared in an adjacent waste dump in 1969 and has continued intermittently to the present. Each period of movement appears to be coupled with deepening of the pit.

Causes

The causes of the south slide are a combination of features: two major intersecting structural features, past-underground mining, and mine waste disposal. (Figure four) A north-south and a northeast-southwest fault intersect about 1200 feet from the pit limit, effectively severing the slide area from the surrounding rock mass. Heavy mining by the cut and fill method near the turn of century removed most of the support from beneath the area. During the development of both the early pit and the present pit, this area was used as a waste dump because of its proximity to the mining area. In some areas the fill is over 225 feet deep. (Figure five) In short, the south section is a dissected, floating, heavily loaded unit with its toe continually being removed by mining. Figure six gives a cross-section of the area.

Effects

The south slide, thus far, has had no adverse effect, because it constitutes the final toe, has no structures nearby, and all the land is held by the company. However, sudden failure, although it is unlikely, would result in termination of mining. In December, 1970, a small slide (4.5 million ton) occurred when part of area 1 in figure six failed suddenly though not unexpectedly. Its controls were much the same as the neighboring slides and caused little more than inconvenience.

Conclusions

The south slide, as with the east slide, is largely due to rock broken during previous mining. It differs in that structural controls also play a large part.

Thorough knowledge of the situation and its controls coupled with continuous monitoring (which has shown a correlation between periods of acceleration and deepening) make this slide much less dangerous than its contemporary to the east. This type of mining operation is quite flexible and after each successive toe removal or during periods of acceleration, mining is shifted to different sections of the pit. Consequently, no production is lost, making this slide a "failure."

GENERAL CONCLUSIONS

Pitting of an area previously mined by underground methods cannot be thought of in the same context as an area that has not been mined before. Some of the additional considerations that must be entered into any planning:

(1) What effects did the mining have on the rock properties?

(2) Will the slope angle be governed by structure or old workings?

Of course, many other points may be brought out, but slope-wise these are the most important. In general, it can be said that in any pit development program in a heavily mined district, a company must be prepared to spend additional sums for removal of materials whose competence has been destroyed by subsidence. Also, the placement of mine structures and waste dumps must be governed by a thorough geological examination, instead of by the common economics of proximity.

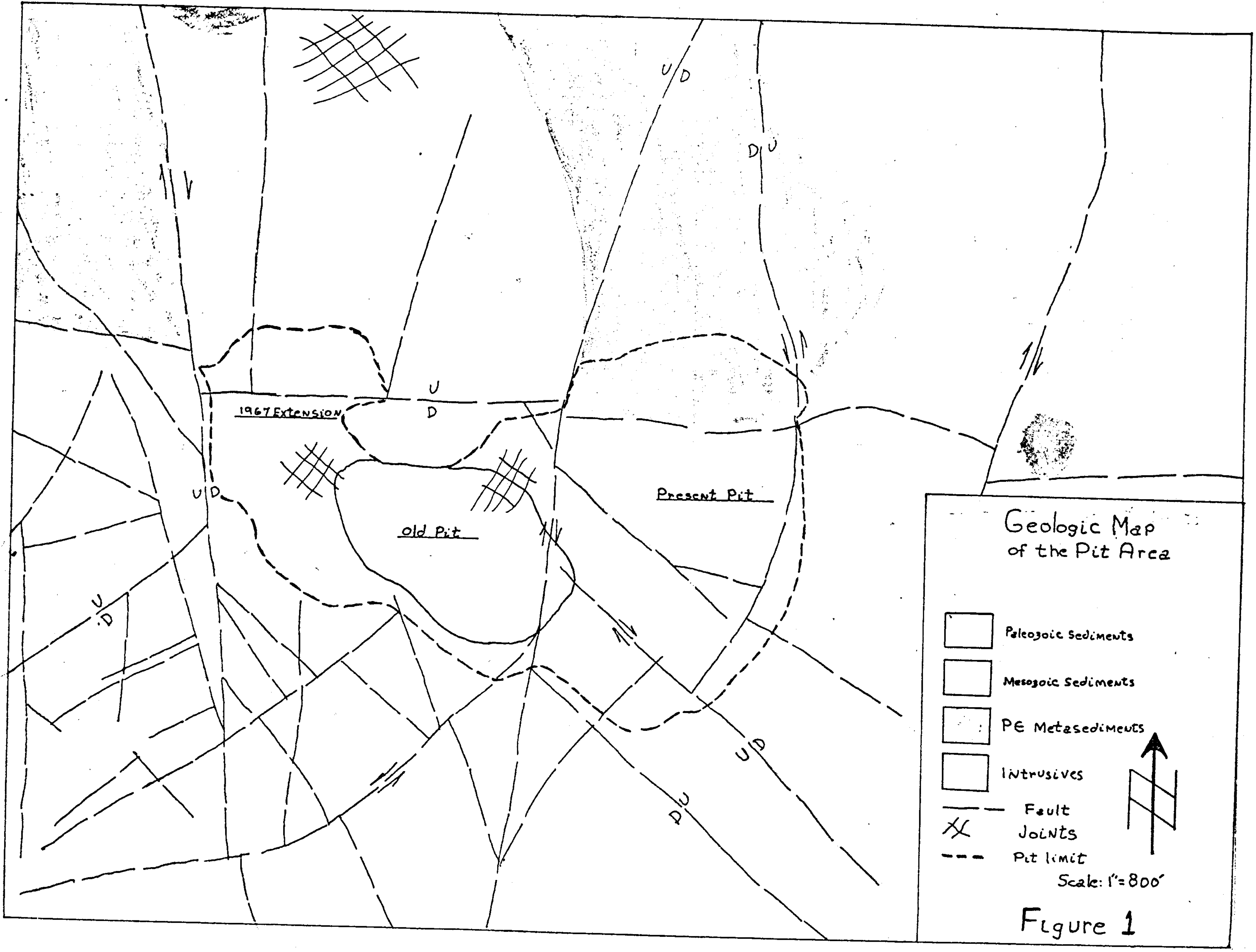

Geologic Map
of the Pit Area
Paleozoic Sediments
Mesozoic Sediments
PE Metasediments
Intrusives
Fault
Joints
Pit limit
Scale: 1"=800'
Present Pit
Old Pit
1967 Extension
U
D
U/D
D U

Figure 1

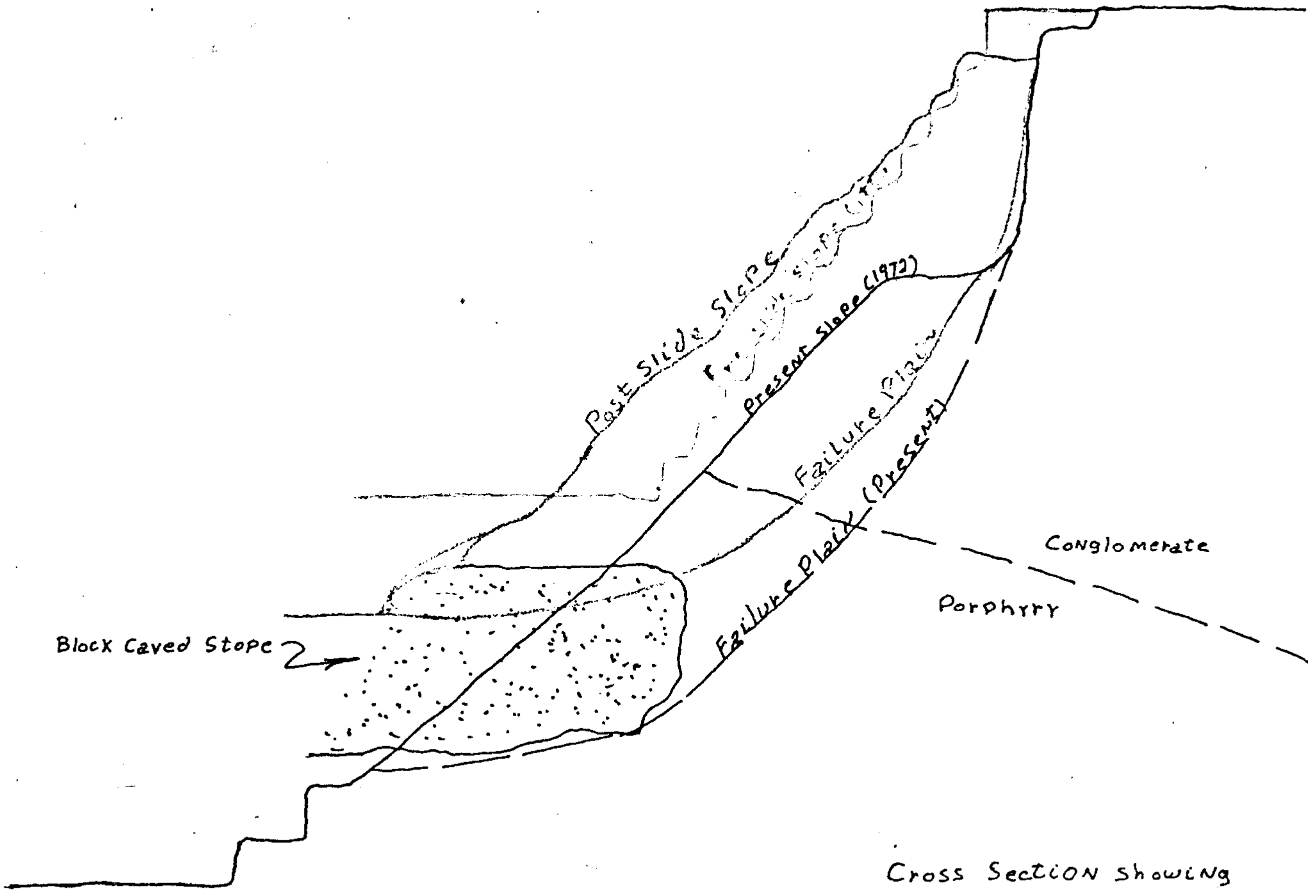


Figure 2

Cross Section showing
East slope at diffrent
stages

Scale:1"≈200'

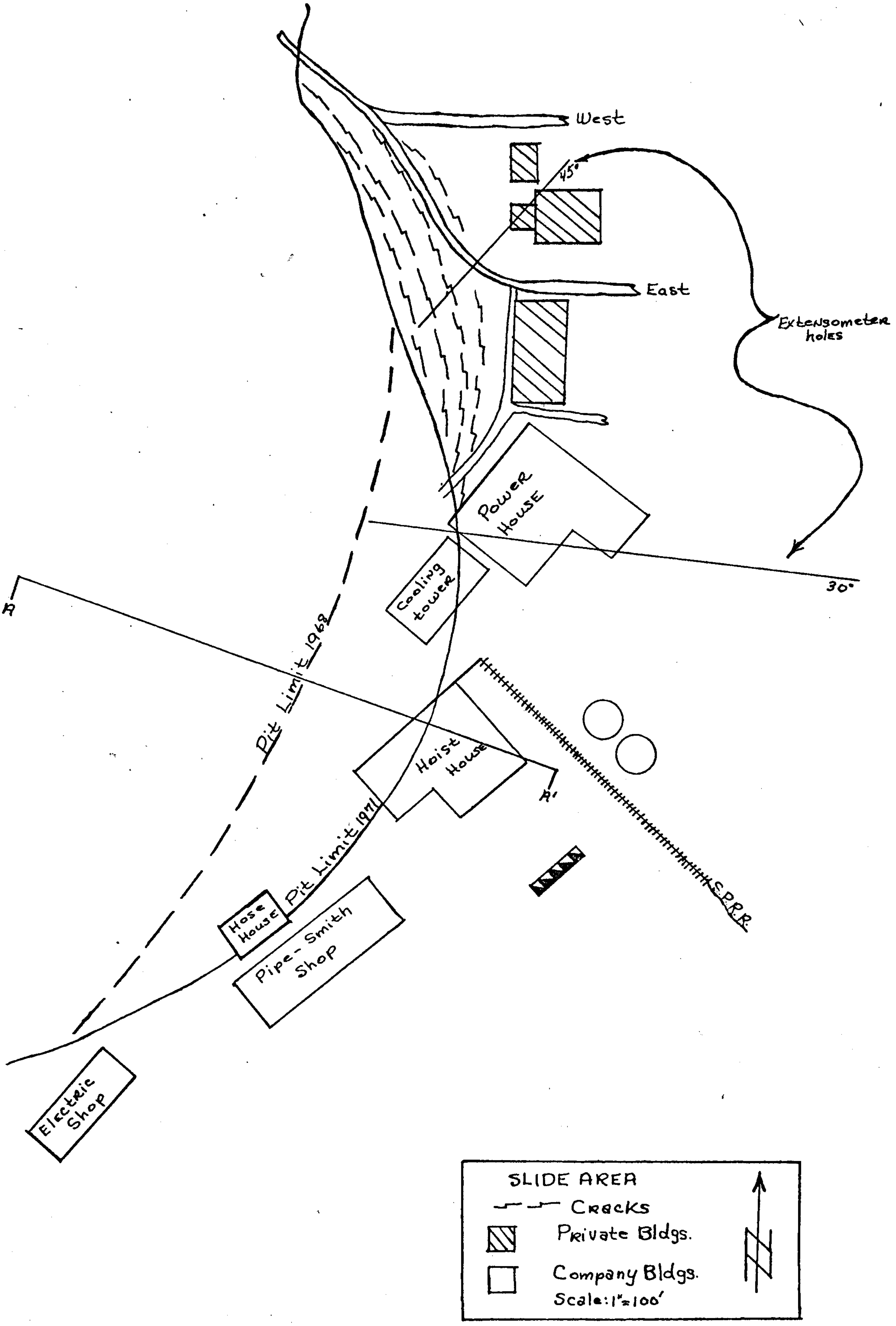

West
45°
East
Extensometer holes
Power House
30°
Cooling tower
A
Pit Limit 1968
Hoist House
A'
Pit Limit 1971
Hose House
Pipe-Smith Shop
S.P.R.R.
Electric Shop
SLIDE AREA
Cracks
Private Bldgs.
Company Bldgs.
Scale: 1"=100'

fig. 3

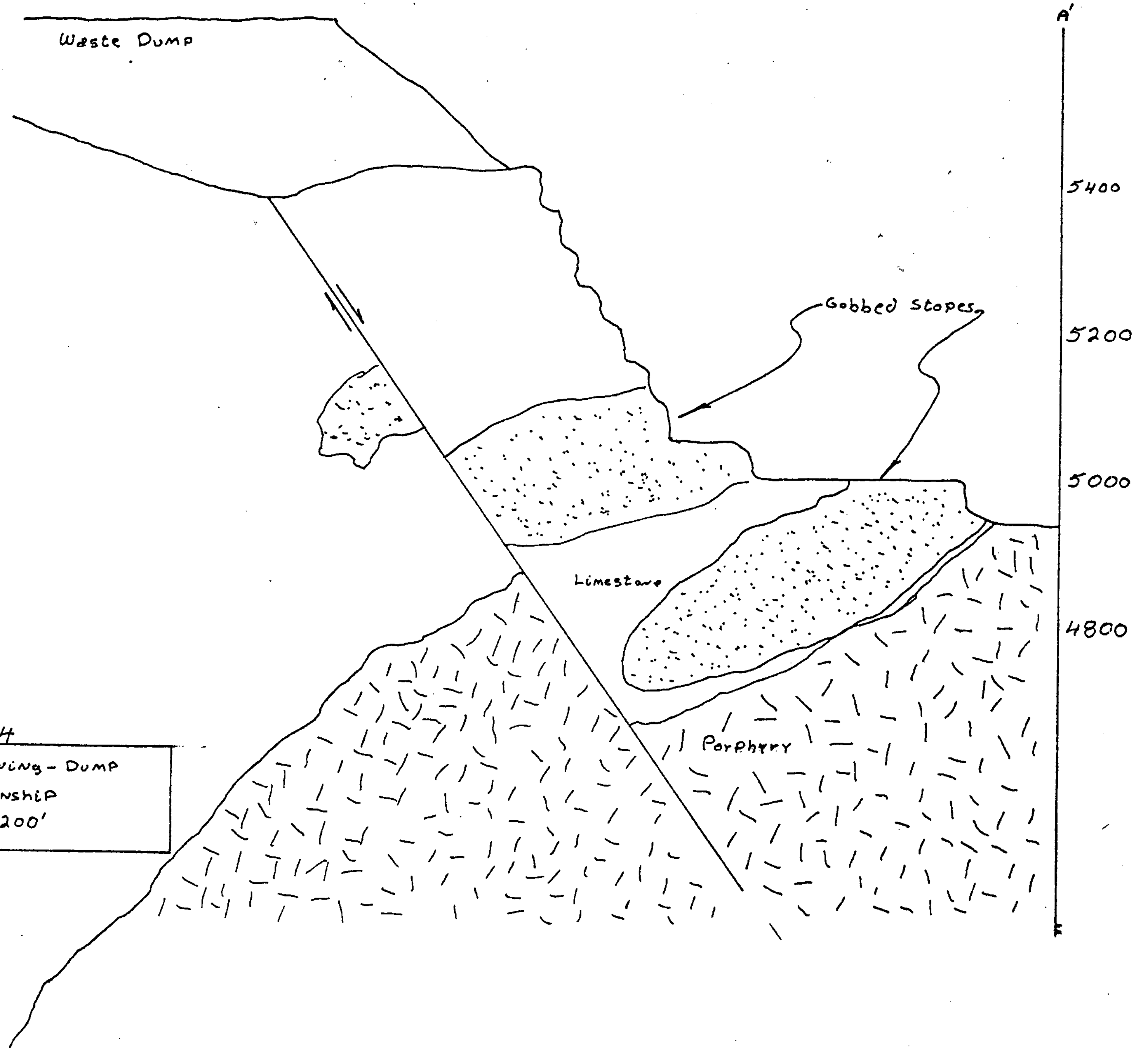


Figure 4

Cross Section Showing - Dump
Fault, Stope relationship
Scale: 1" = 200'

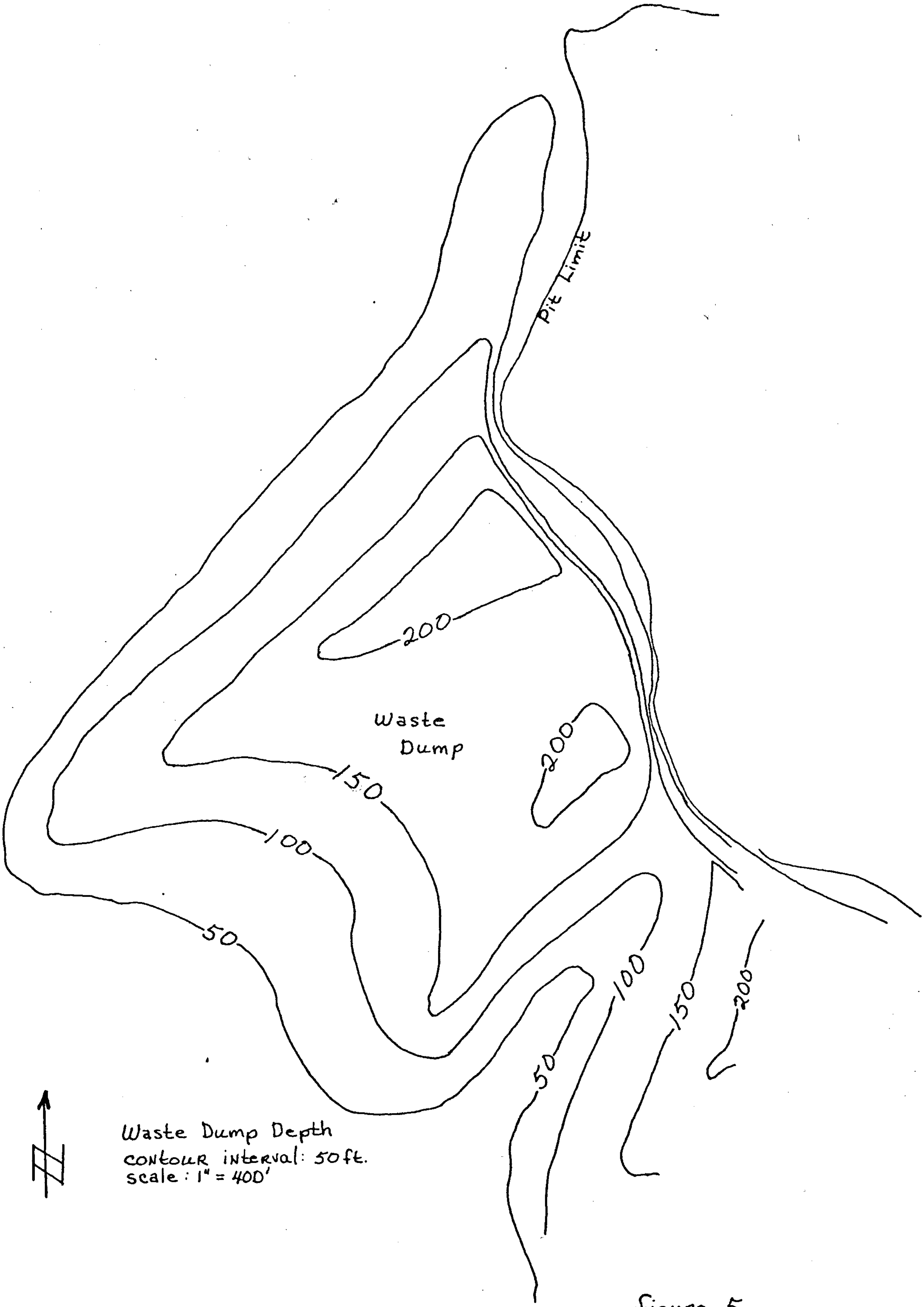
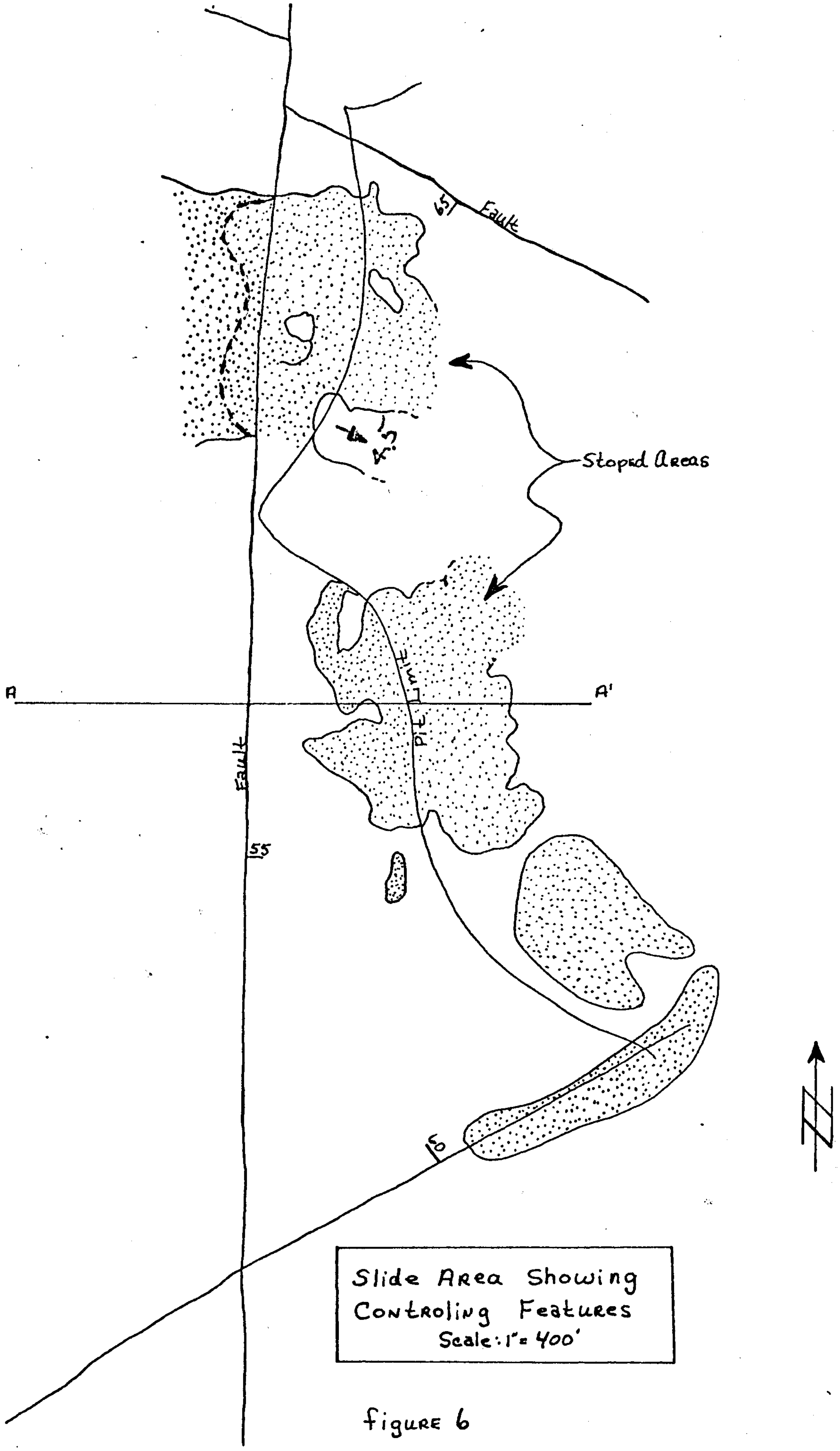

Pit Limit
200
Waste
Dump
200
150
100
50
100
150
200
50
Waste Dump Depth
contour interval: 50ft.
scale : 1" = 400'

figure 5



Slide Area Showing
Controling Features
Scale: 1" = 400'

figure 6