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The Stability Of Slopes In Open Cast Mines And The Economic Implications Thereof

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(3) Final depths of pit of:

(a) 600 feet)
(b) 800 feet) with the corresponding values of ore reserves and overall
(c) 1000 feet) stripping ratios.

Ore reserve and stripping ratio figures for the valuation example were obtained from the geometric analyses carried out on the two pits.

To convert volumes of ore and overburden, given in cu.ft. in the analyses, to tons, the following conversion factors were employed.

Ore . . . . . 13.5 cu.ft/ton
Overburden . . 18.0 cu.ft/ton

The volumetric stripping ratios were converted into tonnage stripping ratios accordingly.

The present value aspect of the valuation also had to be simplified quite considerably. It was assumed that a constant annual income was obtained from the pit, whereas in practice the value of annual income would vary considerably depending on the mining policy of the company.

An example of this is that a mining company might decide to carry out excessive overburden stripping operations in the early stages thus keeping profits down to a reasonable minimum with the idea in view of having low stripping ratios and large profits towards the end of the life of the mine. This is also

a safeguard against deteriorating market conditions and/or increase in working costs with time. This procedure, however, does reduce the present value of the mine in that profits made in the near future have a higher present value than those made in the more distant future.

Present value calculations are, however, at best only rough estimates, because of uncertainty of the future, and it is thought that one is justified in making reasonable simplifying assumptions.

The calculation of the present value was based on an annuity yielding interest on capital at 8% and replacing capital by accumulation at 4%.

The figures given for "Capital Adjustment" are both estimates.

The example of the comparative valuation calculation follows:-

PIT	A	B
Cut-off grade	1.5%	1.5%
Final Depth	800'	800'
Final Slope angle β . . .	45°	45°
Ore Reserve (tons)	34,400,000	45,000,000
Overburden (tons) . . .	175,000,000	315,000,000
Overall Stripping ratio .	5.1 : 1	7 : 1
Average Mill Head grade .	2.5%	2.5%
Tons of Copper in reserve.	860,000	1,125,000
Yearly production of copper	57,400	75,000

PIT		A	B
DAILY PRODUCTION.			
Copper (tons) . . .		185	242
Ore (tons) . . .		7,400	9,700
Overburden (tons) . . .		37,800	68,000
Life of Pit (years) . . .		15	15
Prod. cost/ton of copper	£	104	98
Amortization on Capital	£	12	12
Total cost/ton of copper	£	116	110
Revenue/ton of copper	£	200	200
Gross yearly profit (A)	£	5,500,000	7,650,000
Amortization	£	690,000	900,000
		4,810,000	6,750,000
Allowance for depletion	£	1,300,000	1,900,000
Taxable income	£	3,510,000	4,850,000
Tax at 25% ... (B)	£	880,000	1,210,000
Net annual profit (A-B)	£	4,620,000	6,440,000
Total Profit	£	69,500,000	96,600,000
Present value	£	36,000,000	50,000,000
Capital adjustment	£	15,000,000	25,000,000
Net Present Value	£	21,000,000	25,000,000

CHAPTER 8.

SUMMARY OF CONCLUSIONS.

(1) Slope stability problems can be approached theoretically, and they can be analysed by using existing methods of analysis.

(2) The results obtained from a theoretical slope stability analysis are at best only a fair indication of what exists in practice. Because of the imponderable geological variations in a large open cast mine, it cannot be expected that tests, field observations and calculations will provide absolute answers to slope stability problems.

(3) The final outcome is invariably that the engineer has to make a decision based on his own experience of the problem. This type of work is done to provide a background so that judgment in this field can be developed, enabling "educated" decisions to be made.

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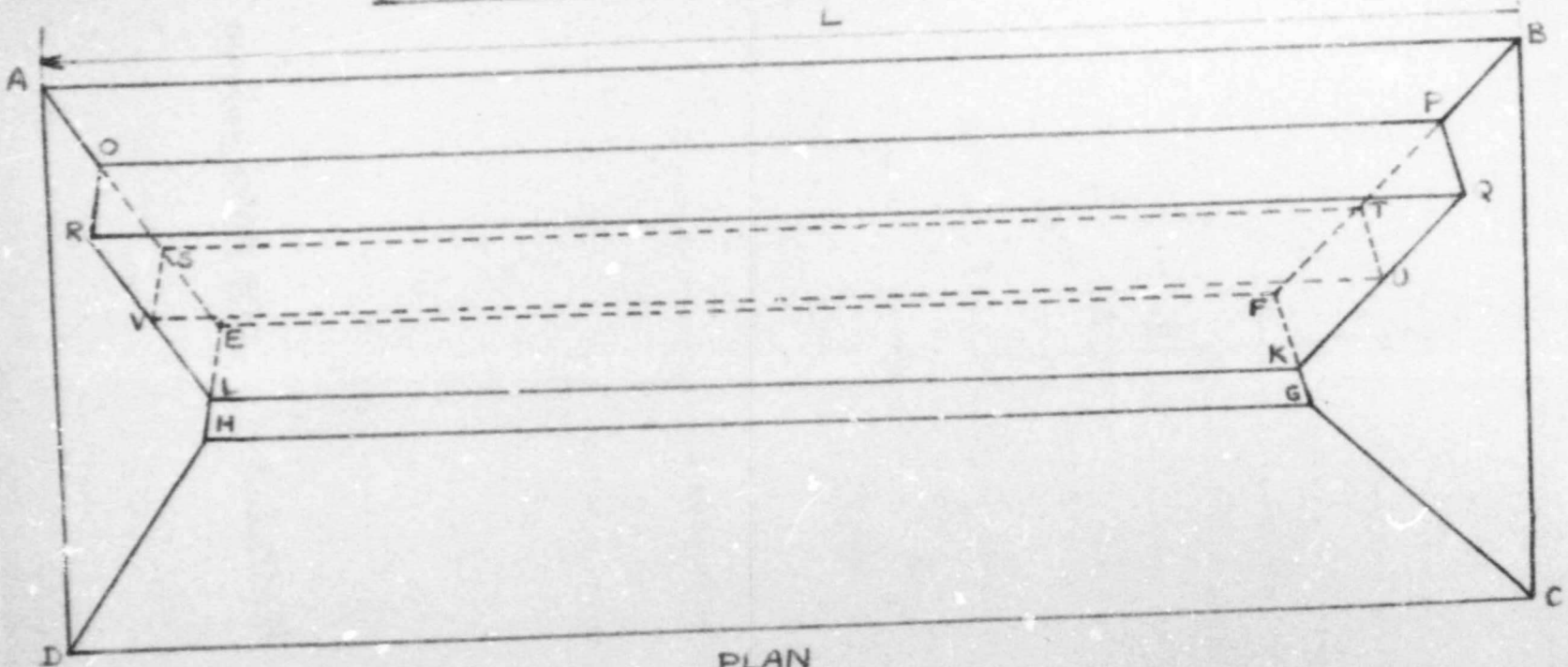
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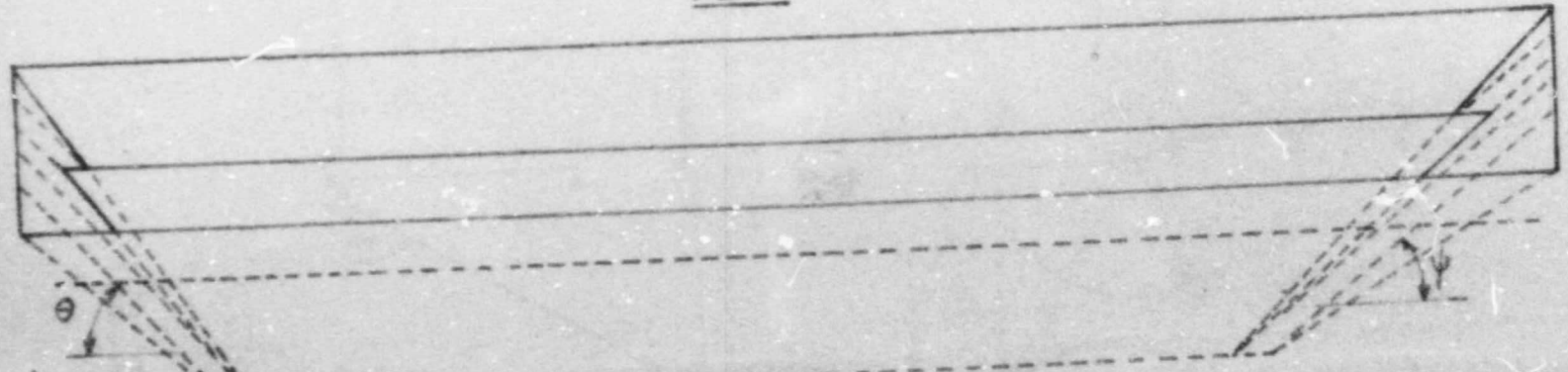
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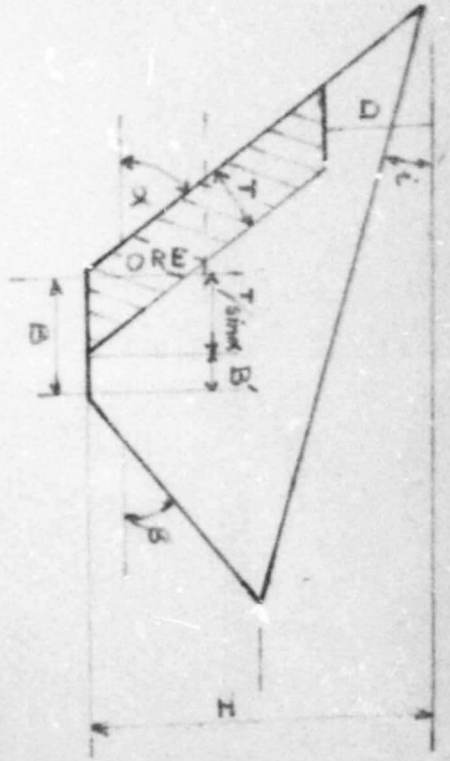
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SHAPE AND SPECIFICATIONS OF PIT A.



PLAN





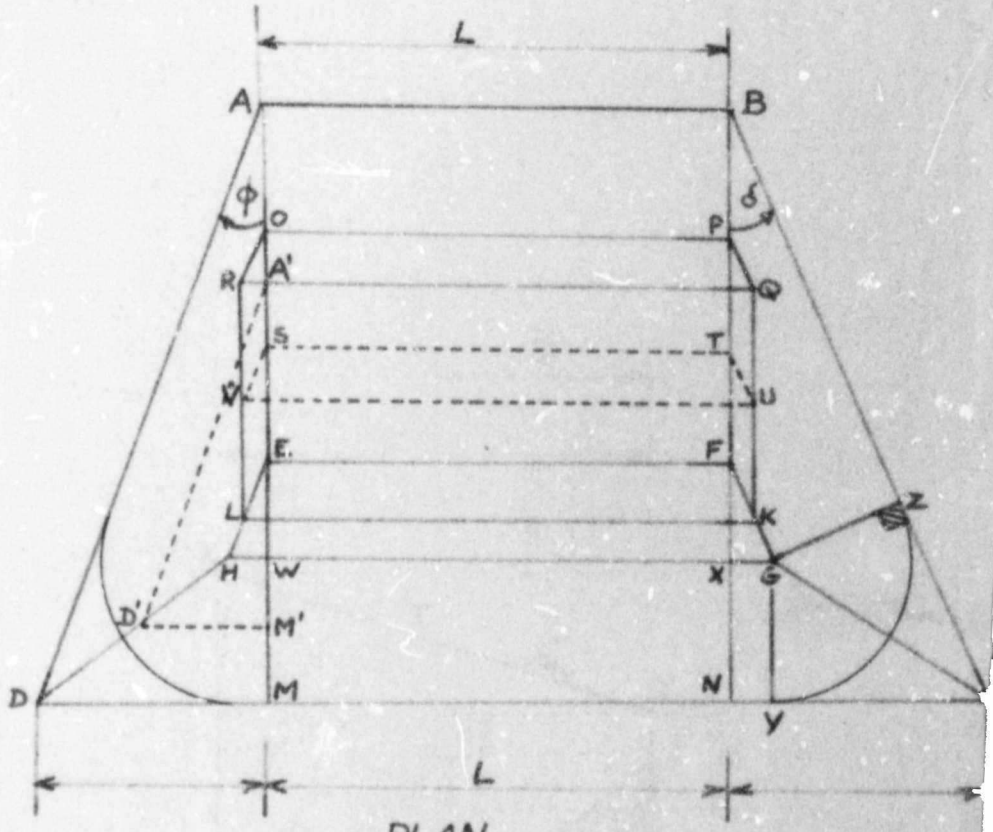
Orebody OPQR-EFKL

Cent. area STUV-----

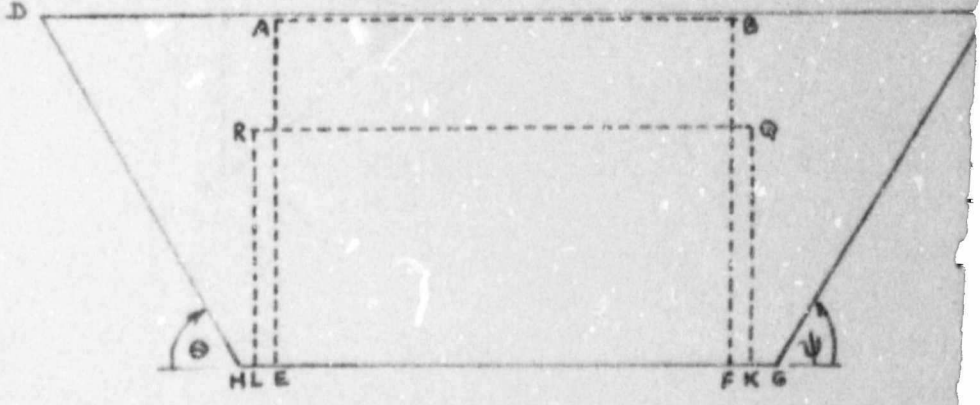
$B = \frac{T}{\sin\alpha} + B'$

B' represents space for

SHAPE AND SPECIFICATIONS OF PIT B.



PLAN



OREBODY OPQR-EFKL. ELEVATION

Fig 2

SECTION THROUGH PIT B.

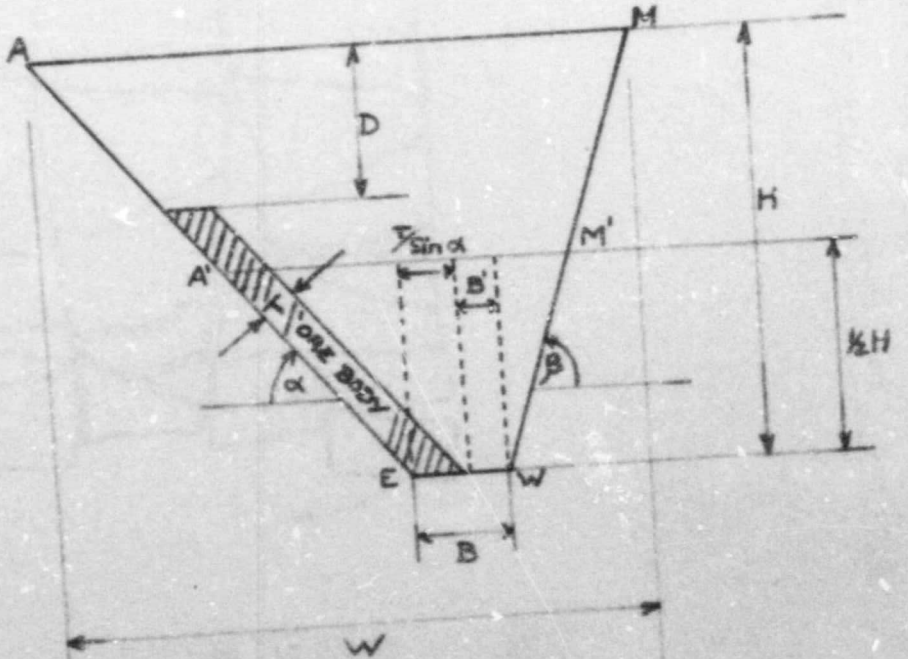
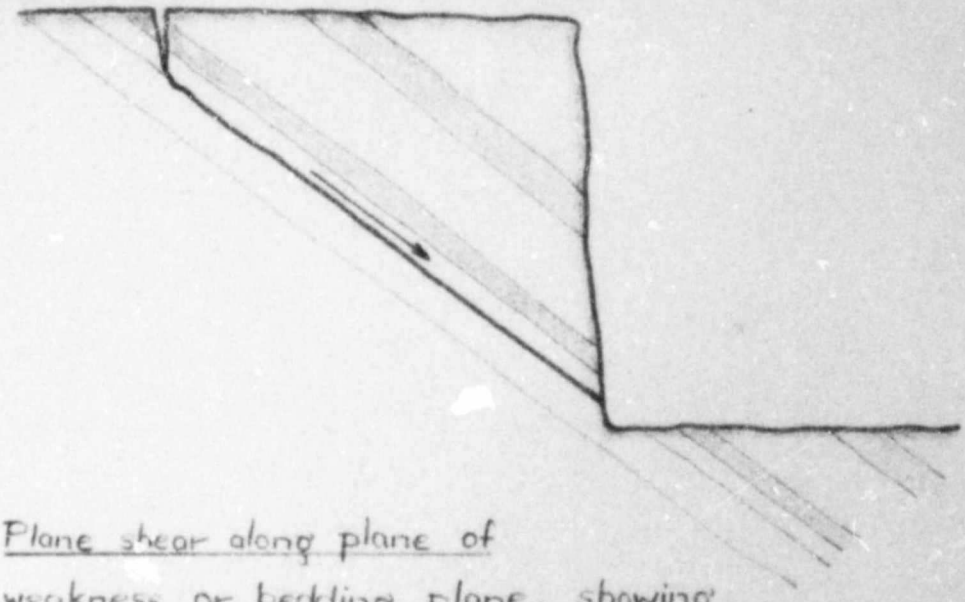
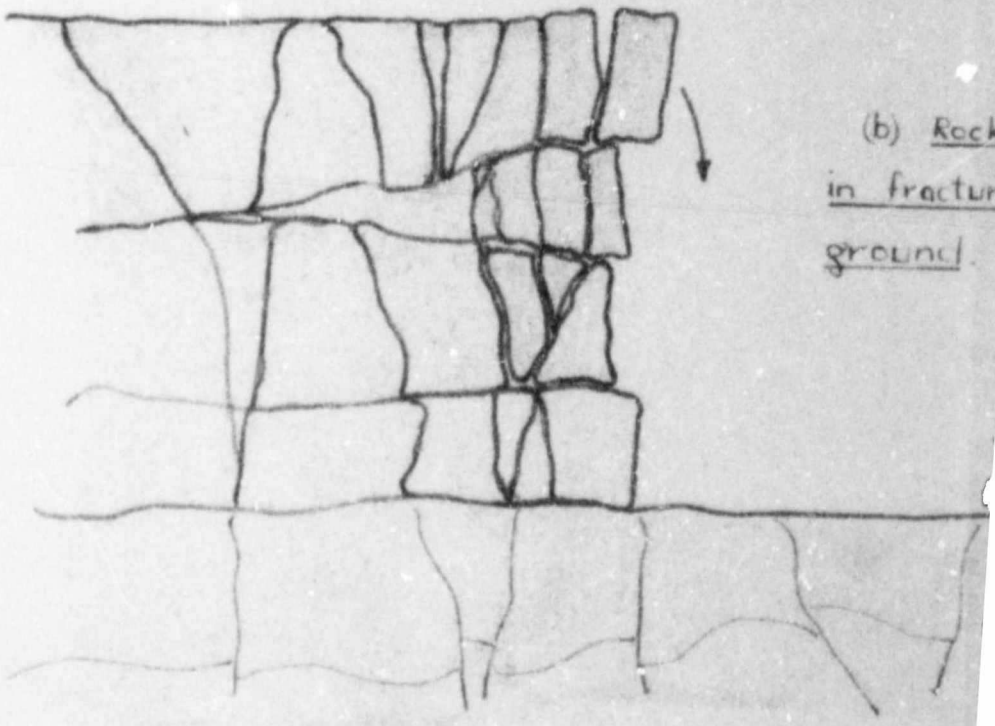


Fig 3



(a) Plane shear along plane of weakness or bedding plane, showing formation of tension crack at surface.



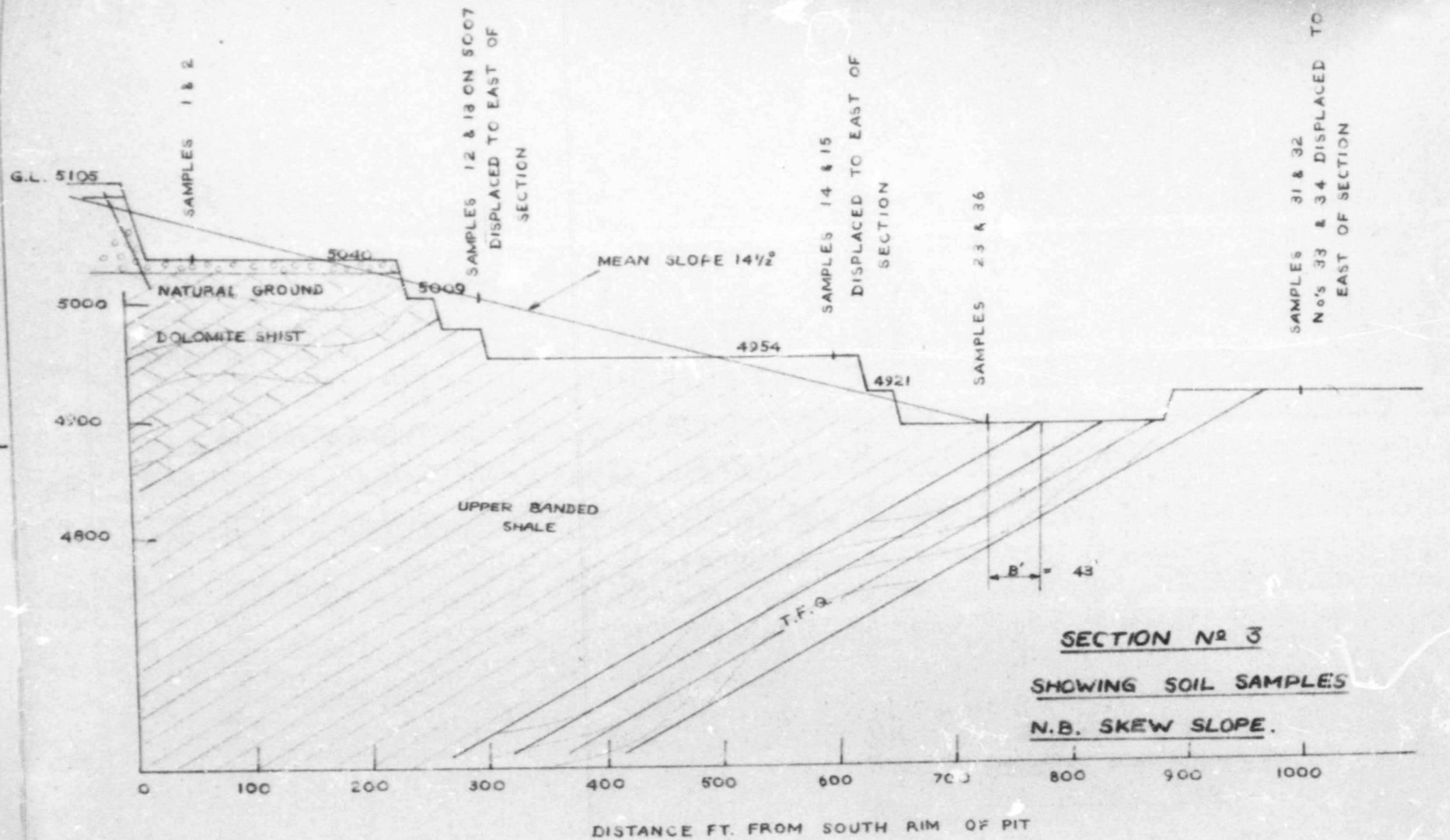
(b) Rock in fractur ground.

Fig

For Fig 5 See
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For Fig 6 See
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For Fig 7 see
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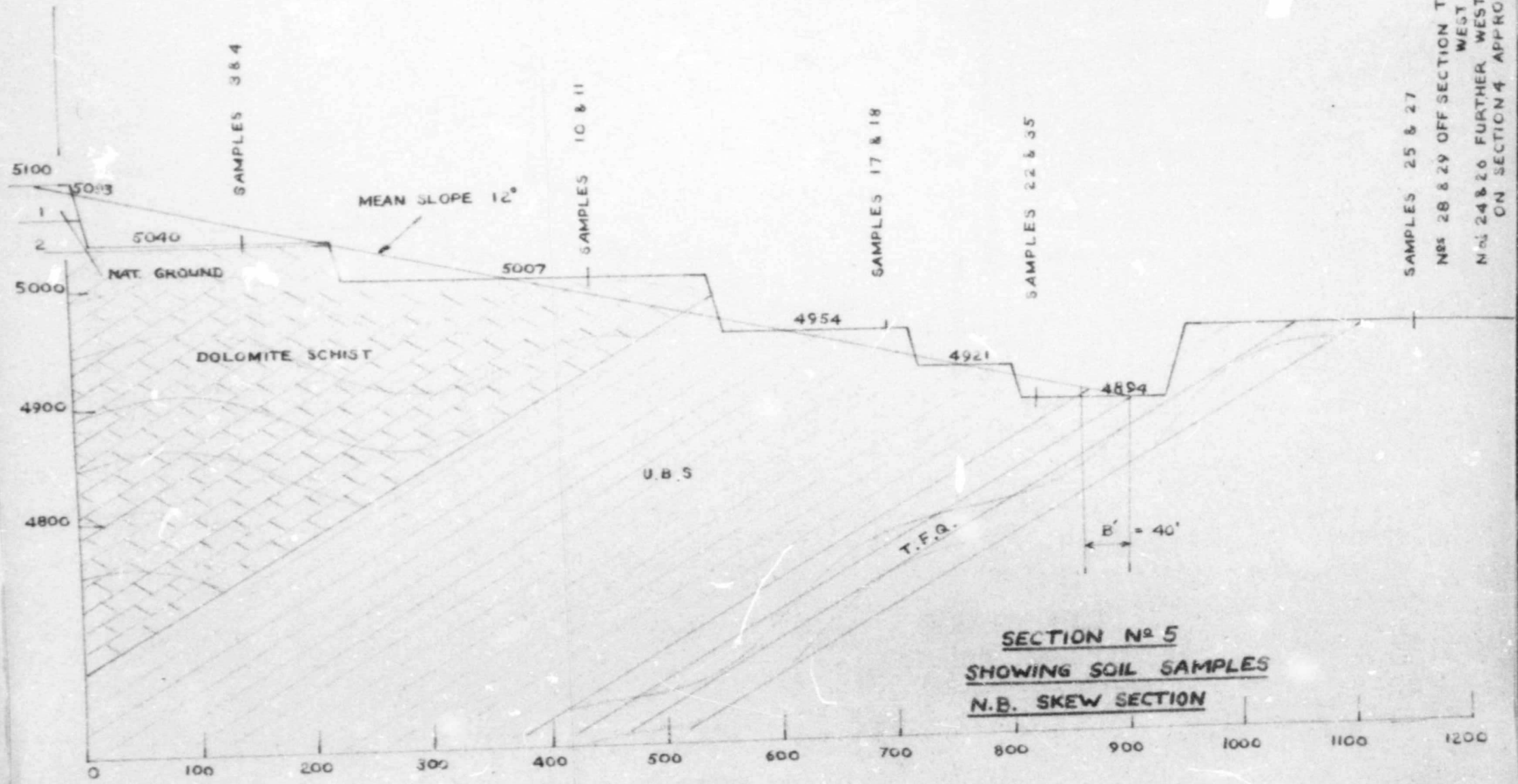


SECTION Nº 3

SHOWING SOIL SAMPLES

N.B. SKEW SLOPE.

Fig 8

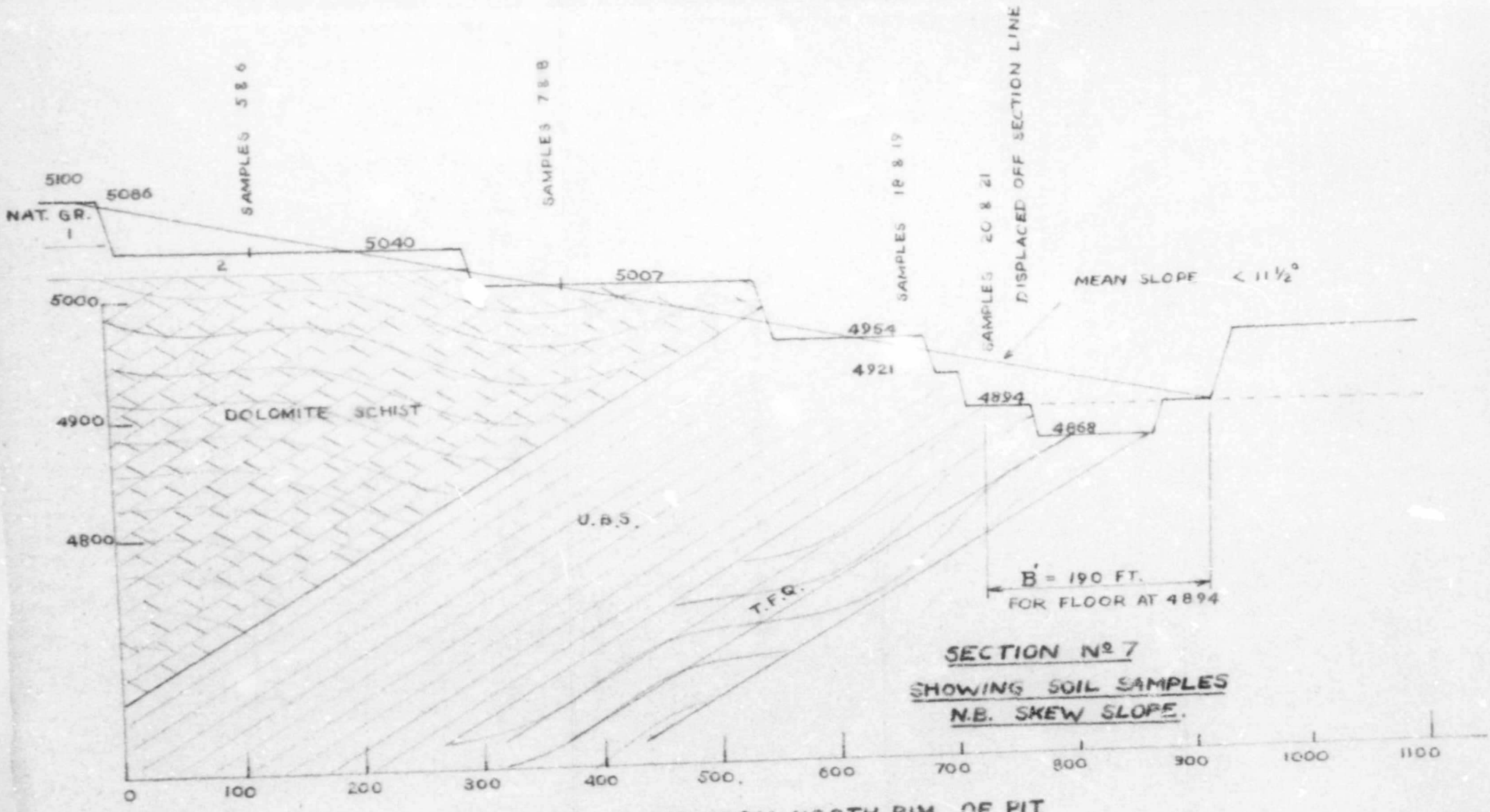


SECTION Nº 5

SHOWING SOIL SAMPLES

N.B. SKEW SECTION

Fig 9

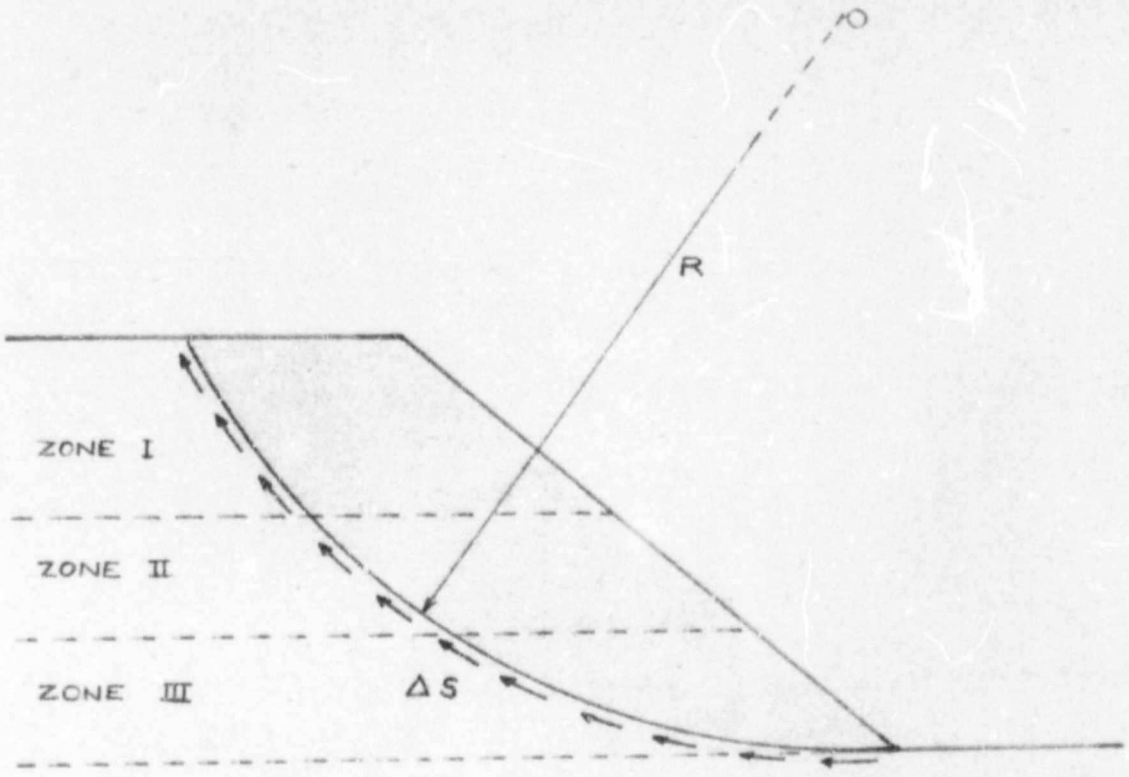


SECTION Nº 7

SHOWING SOIL SAMPLES

N.B. SKEW SLOPE.

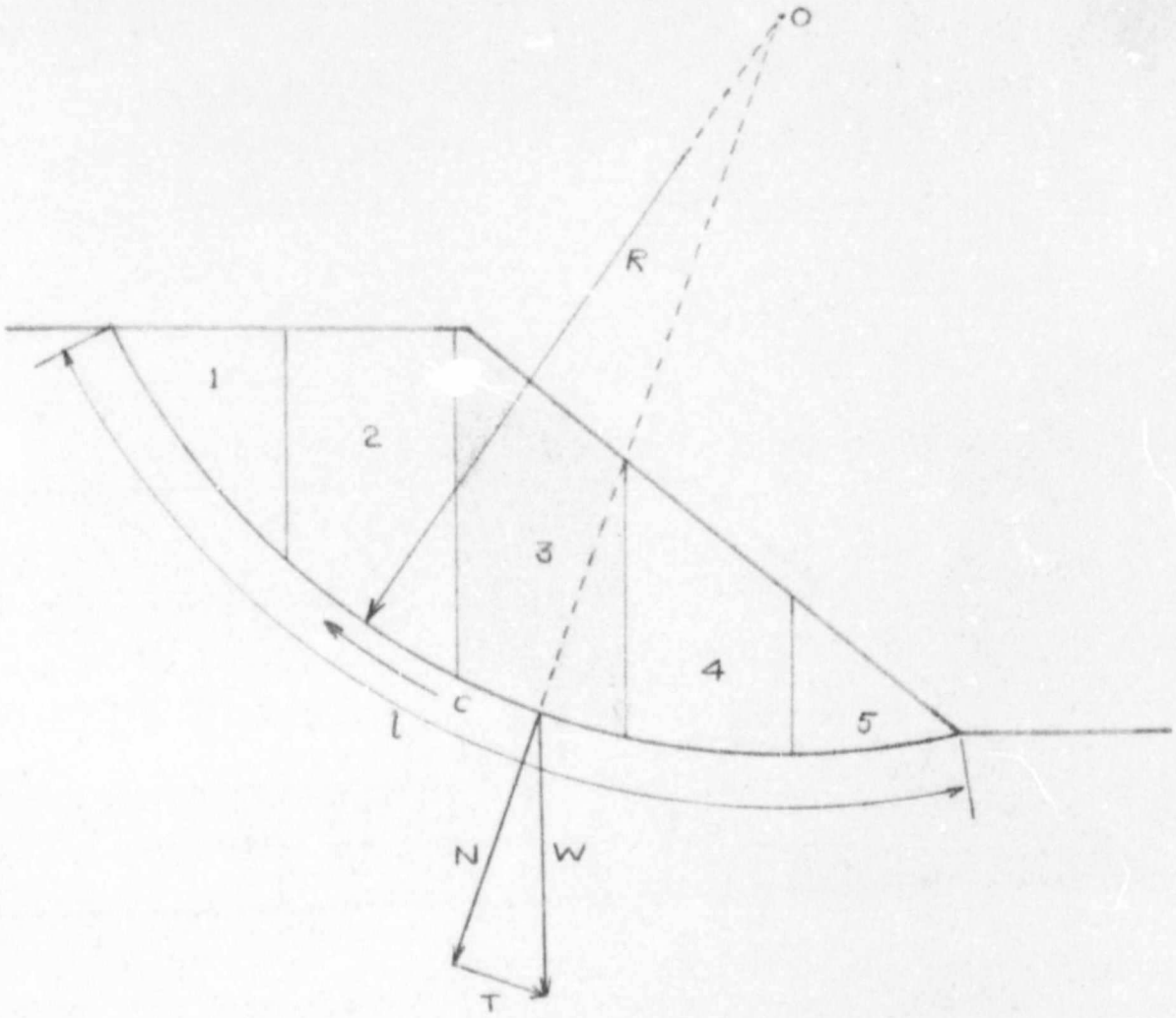
Fig 10



ΔS = Shear resistance of length of arc ΔL

Failure of a slope by a circular arc through the toe. No flow of water through the slope.

Fig 11



Cross section illustrating analysis by means of the Swedish Method of Slices.

l = length of failure arc

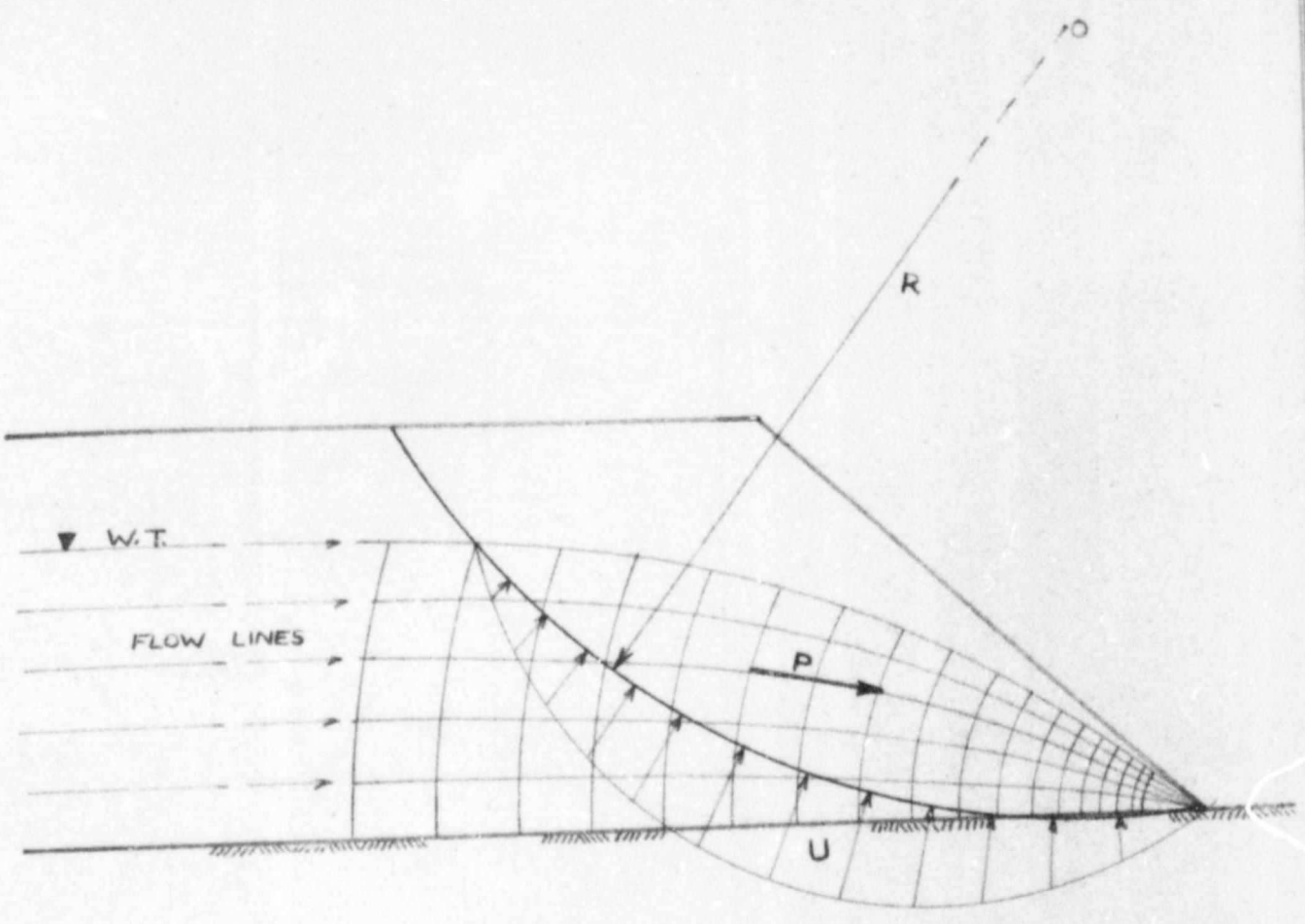
c = cohesion per unit length of arc l.

W = gravitational force.

N = component of gravity normal to failure arc. (friction inducing force).

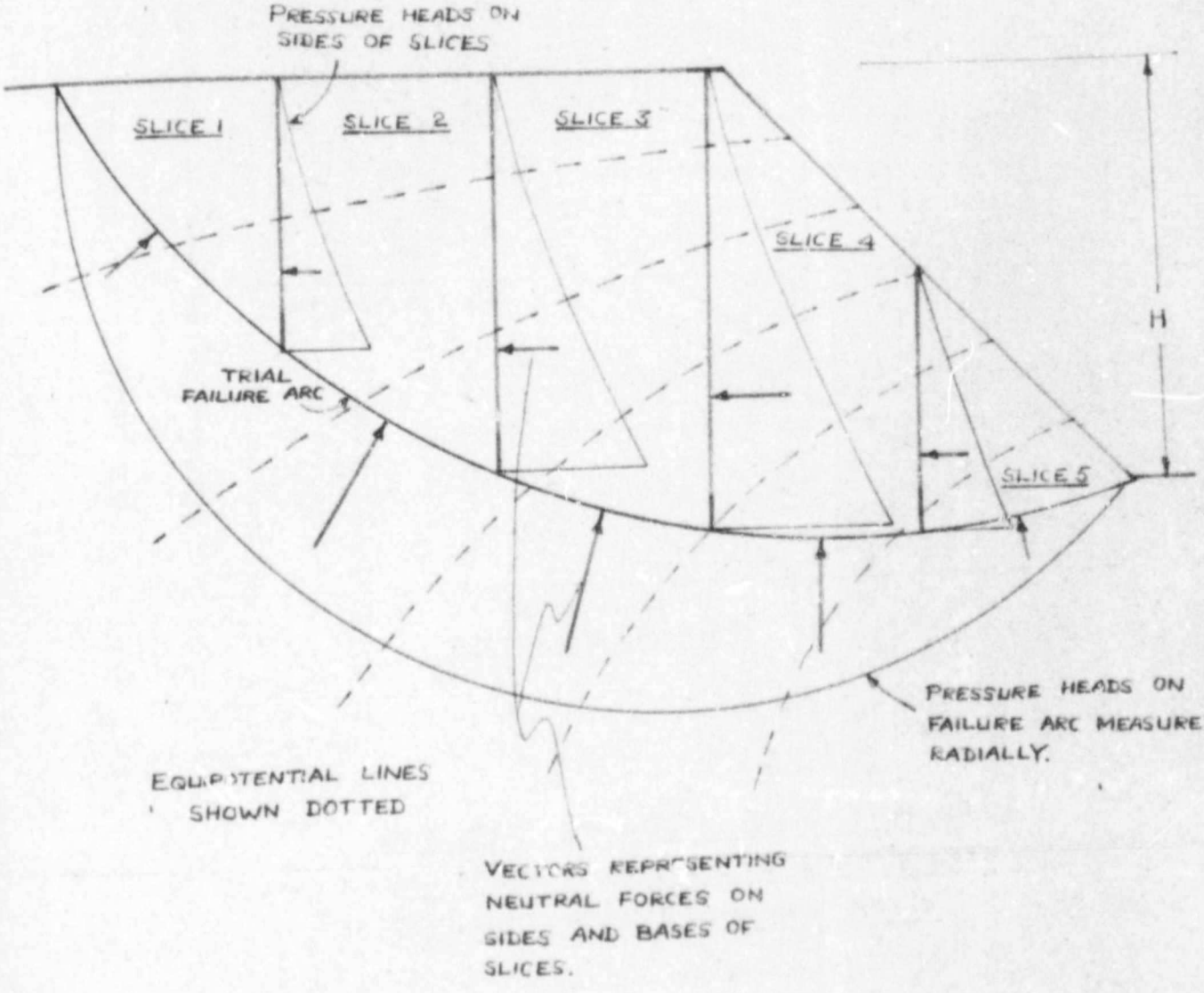
T = component of gravity tangential to the failure arc. (actuating force)

Fig 12.



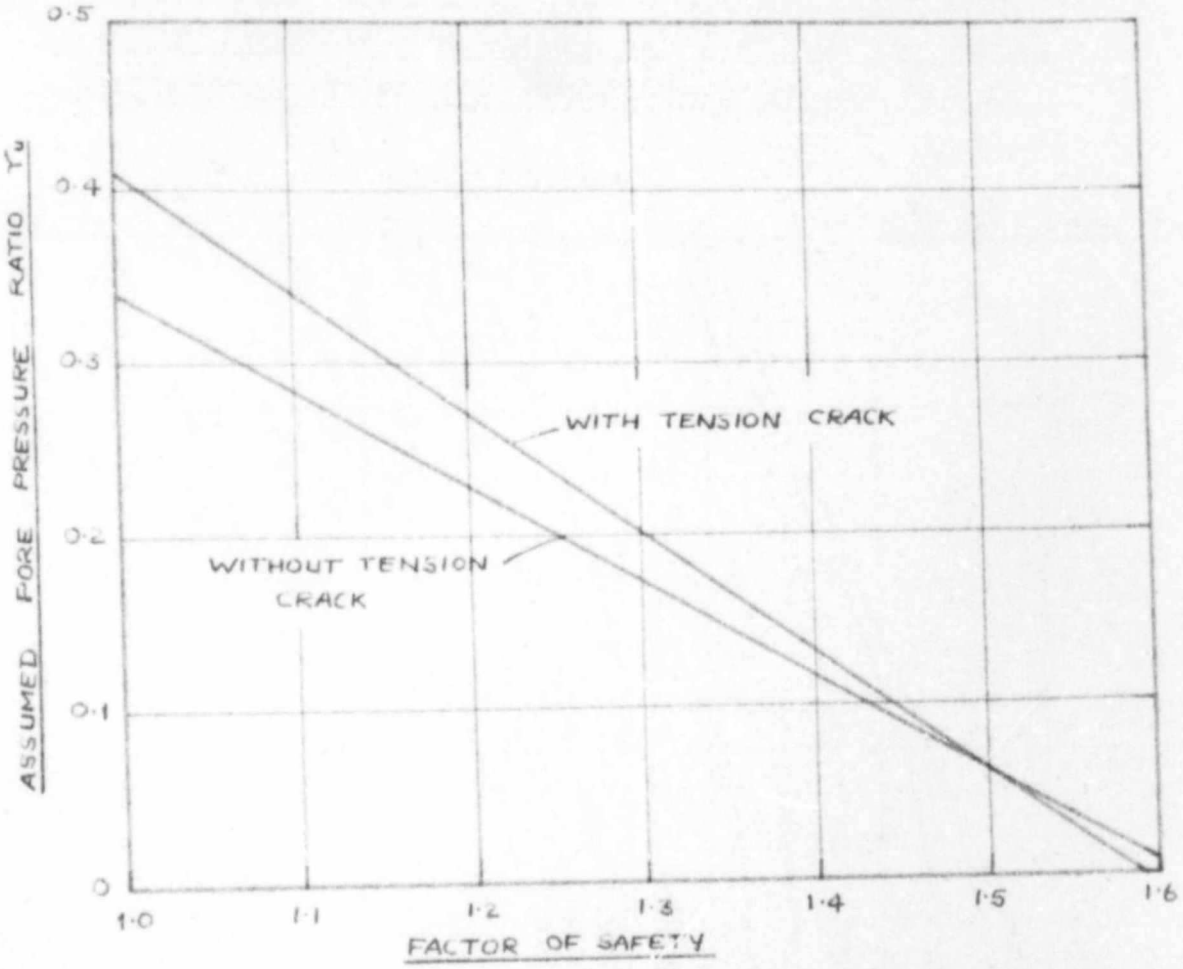
Seepage flow into an excavation from an elevated water table.

Fig 13.



Cross section showing slices and neutral forces.

Fig 14



ANALYSIS OF LOCAL BENCH FAILURE.
VARIATION OF FACTOR OF SAFETY WITH ASSUMED PORE PRESSURE RATIO.

SOIL PROPERTIES

$c' = 720$ LB FT^{-2} $\phi' = 35°$

$\gamma = 127$ LB FT^{-3}

Fig 15.

ISOCHRONES SHOWING PORE WATER PRESSURE DISTRIBUTION WITH DEPTH OVER A 400 ft LAYER OF SOIL WHICH IS CONSOLIDATING DUE TO A DROP IN THE LEVEL OF THE WATER TABLE, ASSUMING THAT NO AIR ENTRY TAKES PLACE.

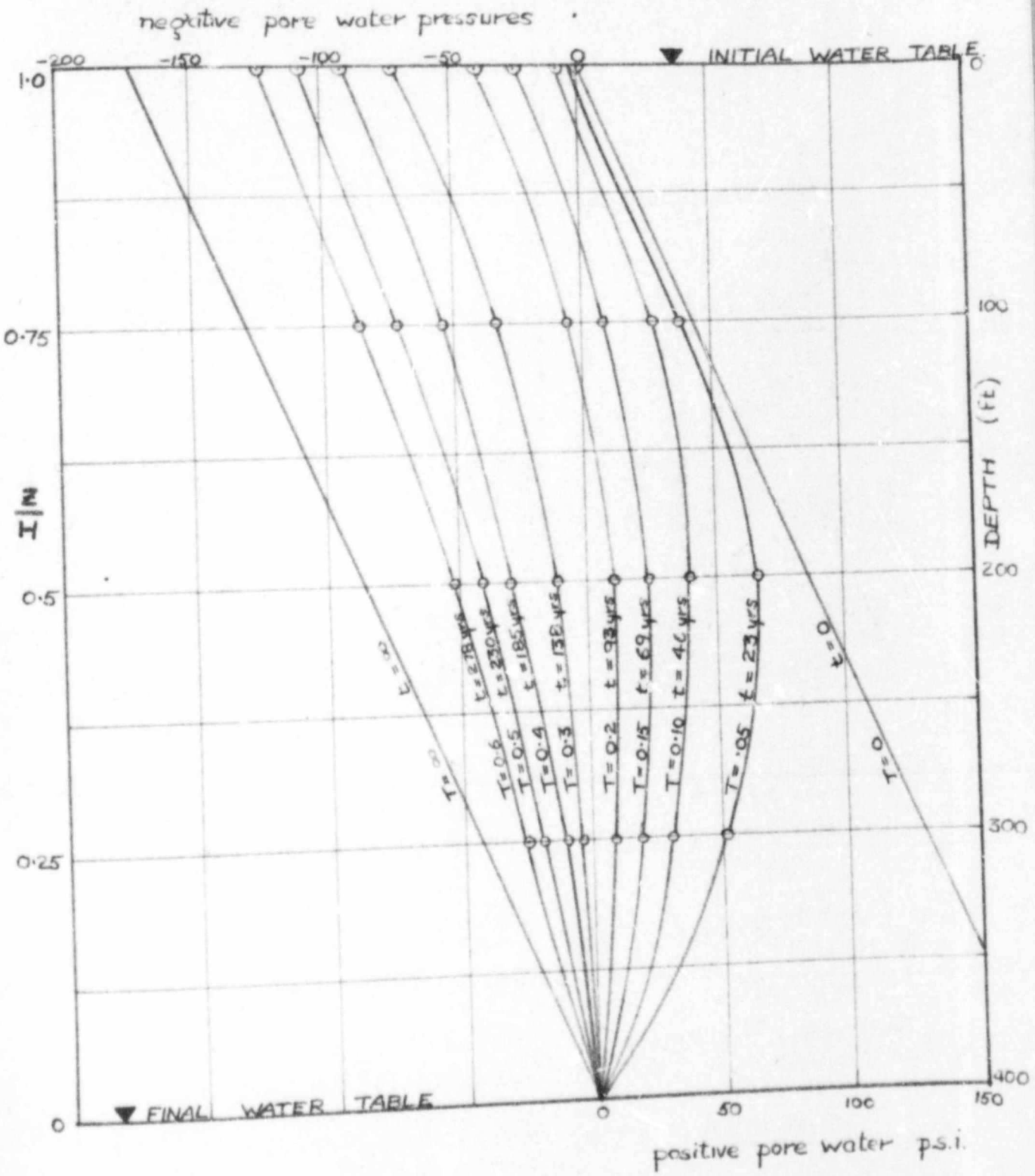


Fig 16(a)

ISOCHRONES AS BEFORE, EXCEPT THAT AIR-ENTRY IS NOW ACCOUNTED FOR.

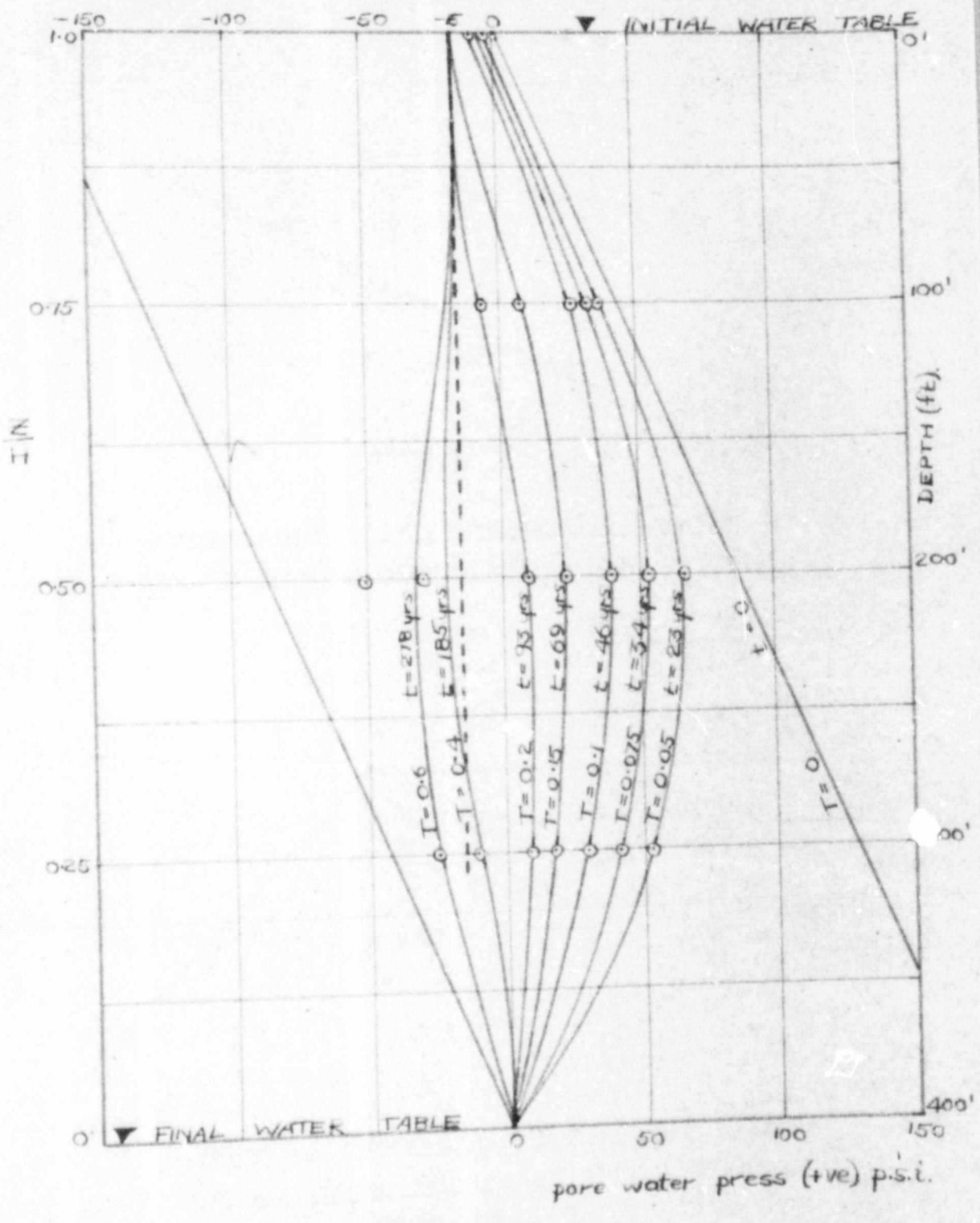
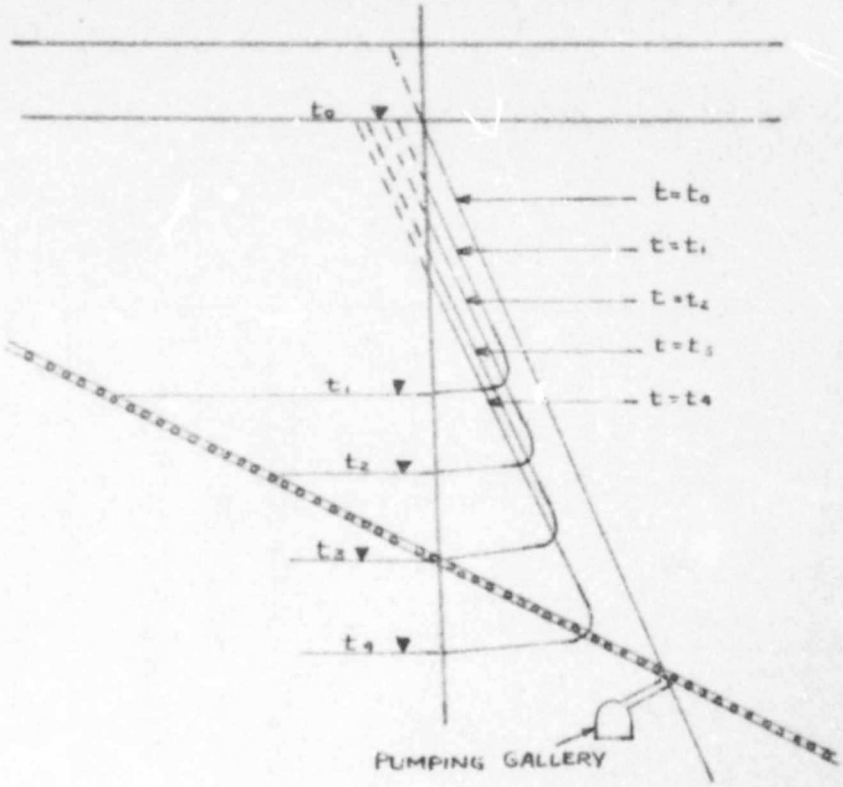
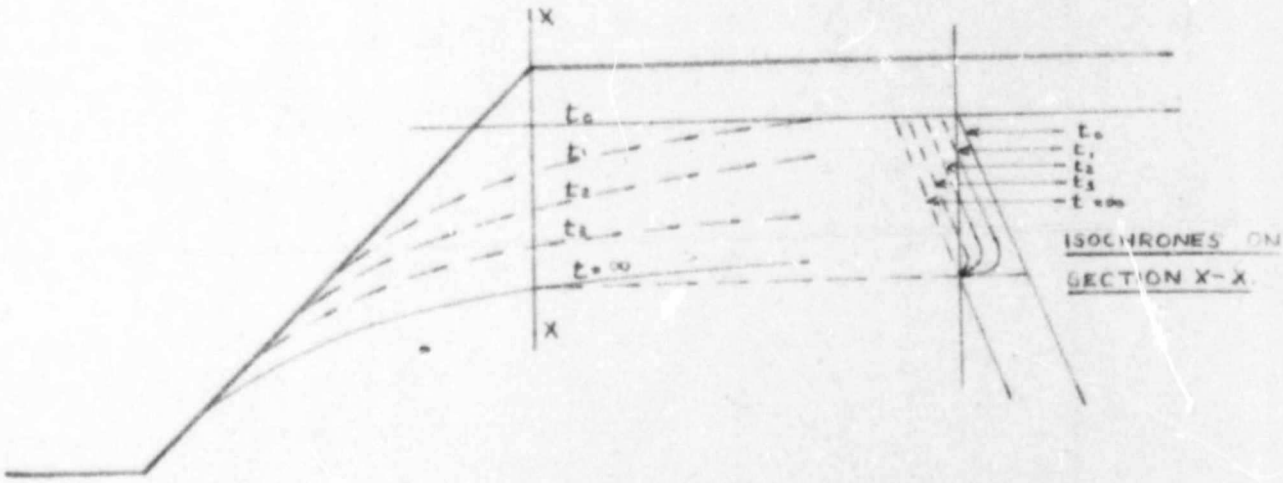


Fig 16(b)



DRAINAGE PROCESS IN COMPRESSIBLE STRATUM DUE TO PUMPING FROM A DIPPING SINK FORMATION

Fig 17



DRAINAGE PROCESS IN COMPRESSIBLE STRATUM DUE TO FLOW INTO A CUT MADE RAPIDLY AT TIME $t=t_0$

Fig 18.

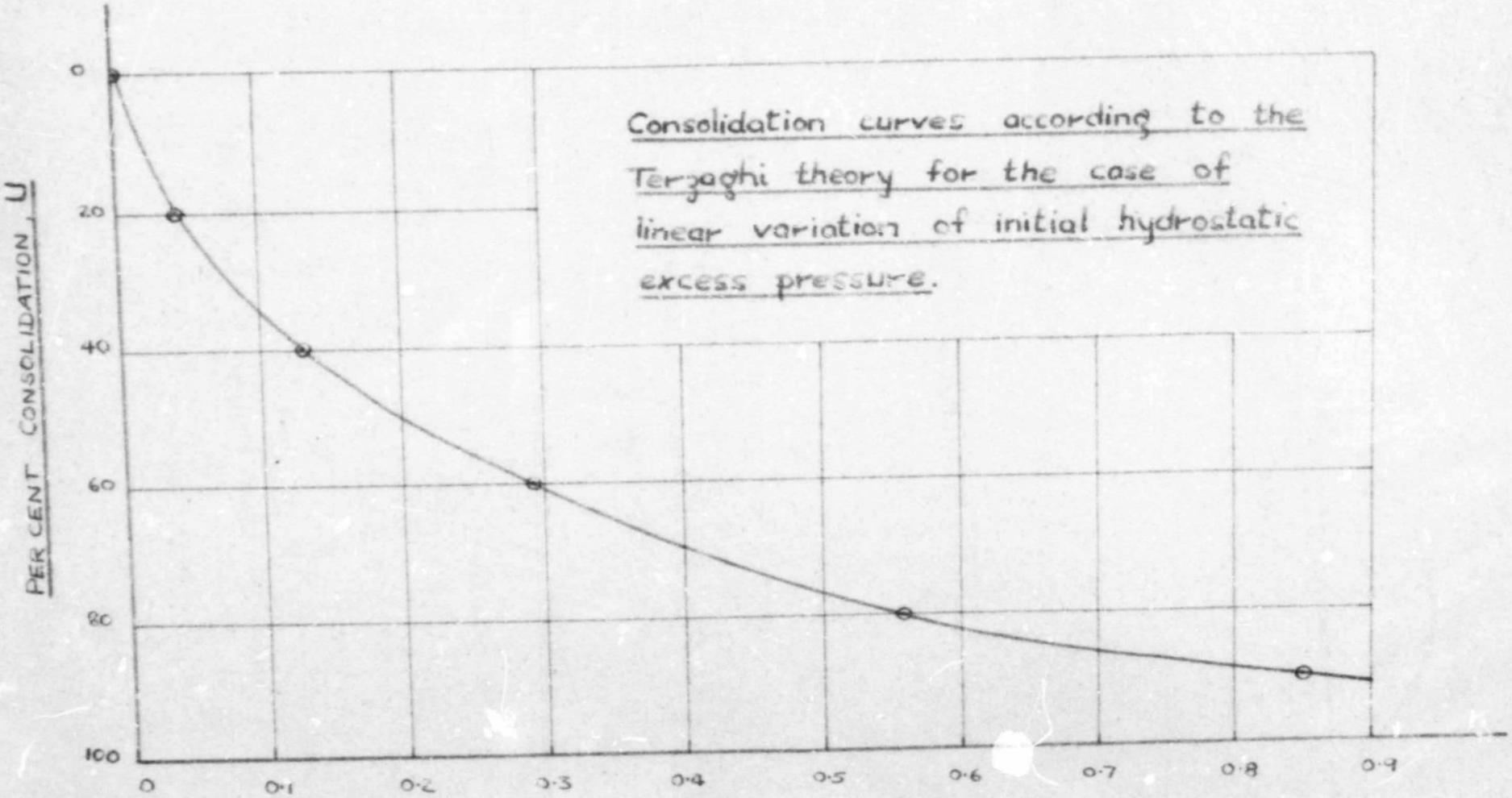
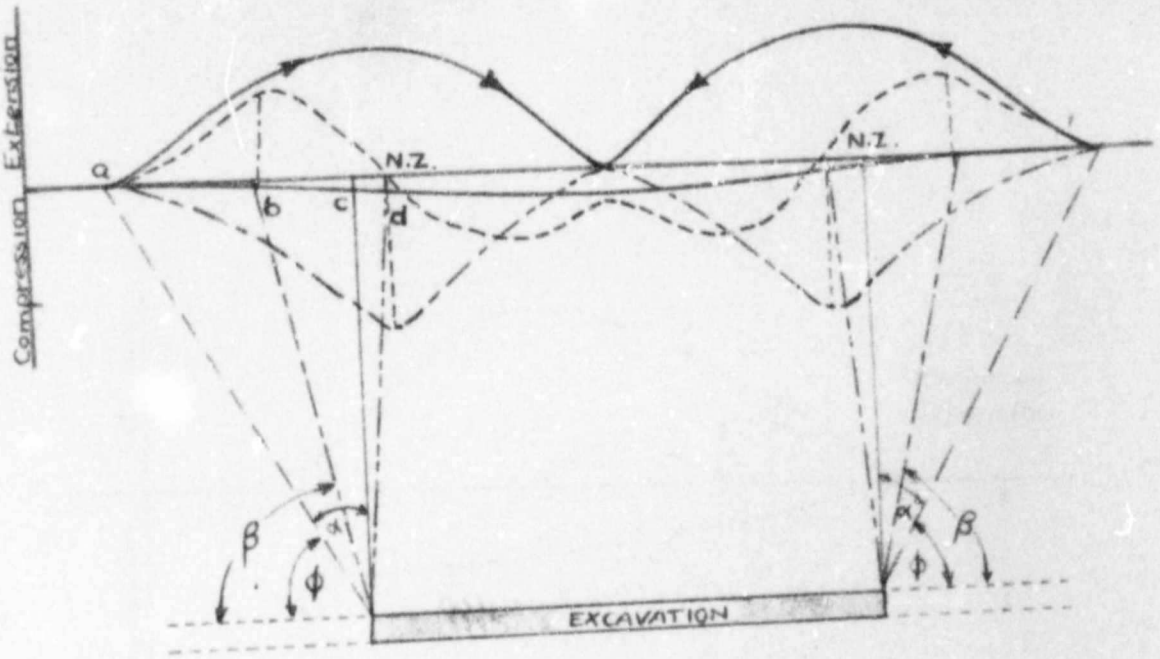

Consolidation curves according to the Terzaghi theory for the case of linear variation of initial hydrostatic excess pressure.
PER CENT CONSOLIDATION, U
0
20
40
60
80
100
0
0·1
0·2
0·3
0·4
0·5
0·6
0·7
0·8
0·9
TIME FACTOR, T

Fig 19



Vertical movement curve (Subsidence)

Lateral displacement curve

Lateral differential movement curve

Vertical differential movement curve

N.Z. Neutral zone

ϕ Angle of influence to horizontal (draw)

α Angle of influence to vertical

β Angle to point of maximum extentional movement (fracture angle)

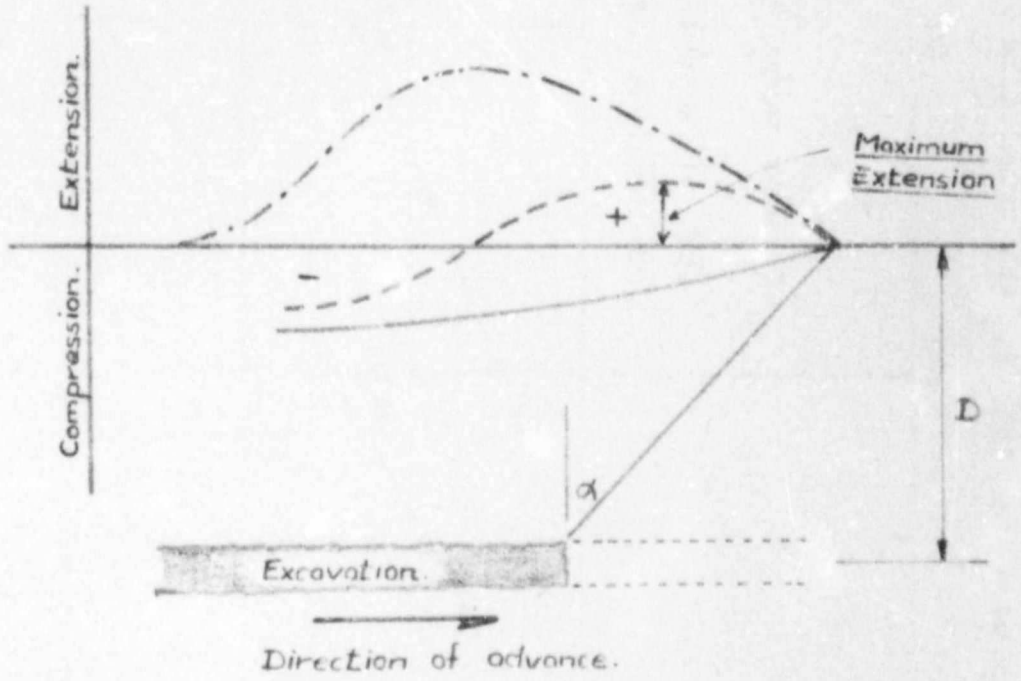
a Point of minimum subsidence and lateral movement.

b Subsidence value at maximum extentional movement.

c Subsidence over solid rib side of extraction

d Subsidence at neutral zone or flexure point.

Fig 20



DYNAMIC CASE

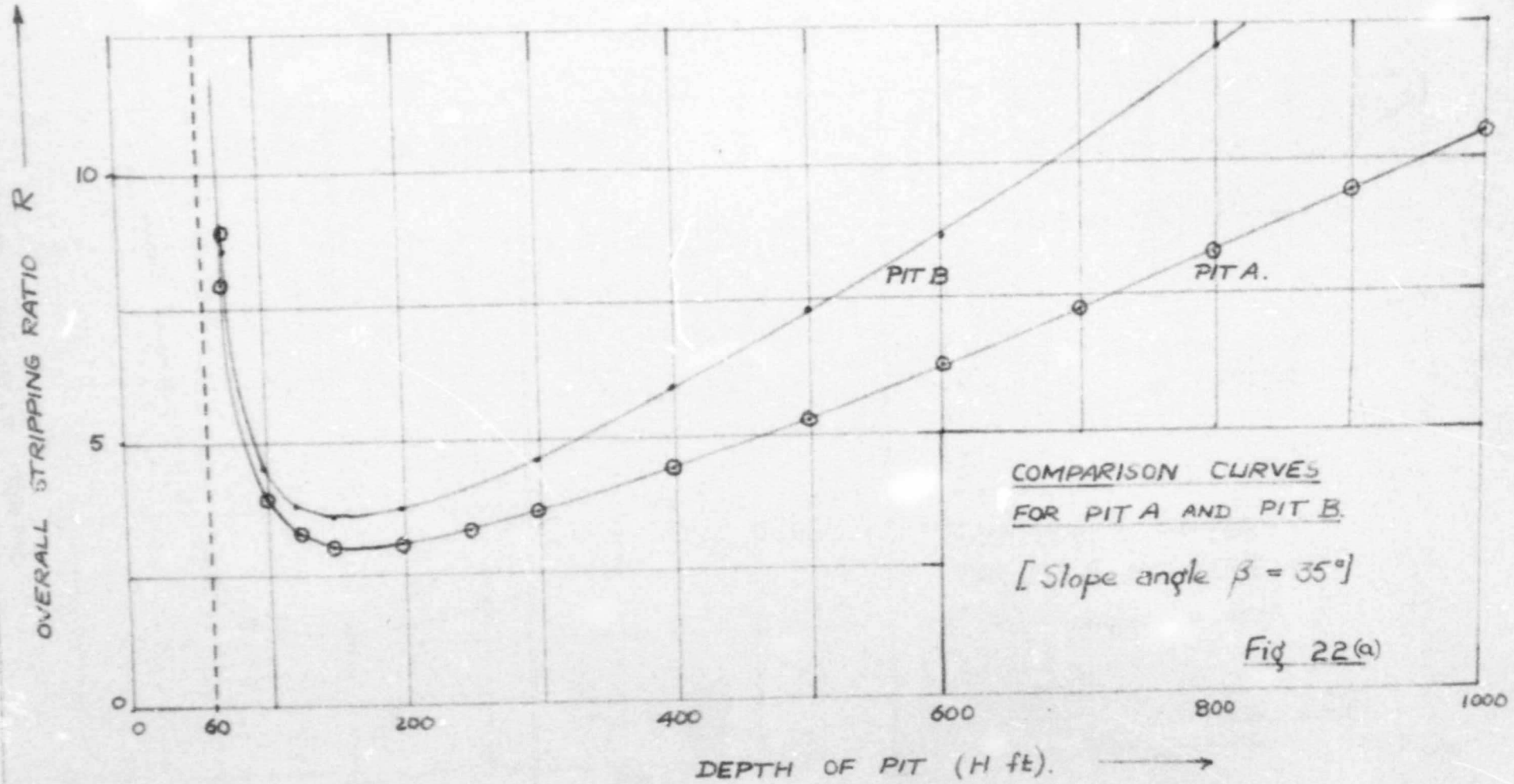
——— Subsidence

– – – – Extension

– – – – Compression

—·—·— Displacement.

Fig 21


OVERALL STRIPPING RATIO R
10
5
0
0
60
200
400
600
800
1000
DEPTH OF PIT (H ft).
PIT B
PIT A.
COMPARISON CURVES
FOR PIT A AND PIT B.
[Slope angle β = 35°]
Fig 22(a)

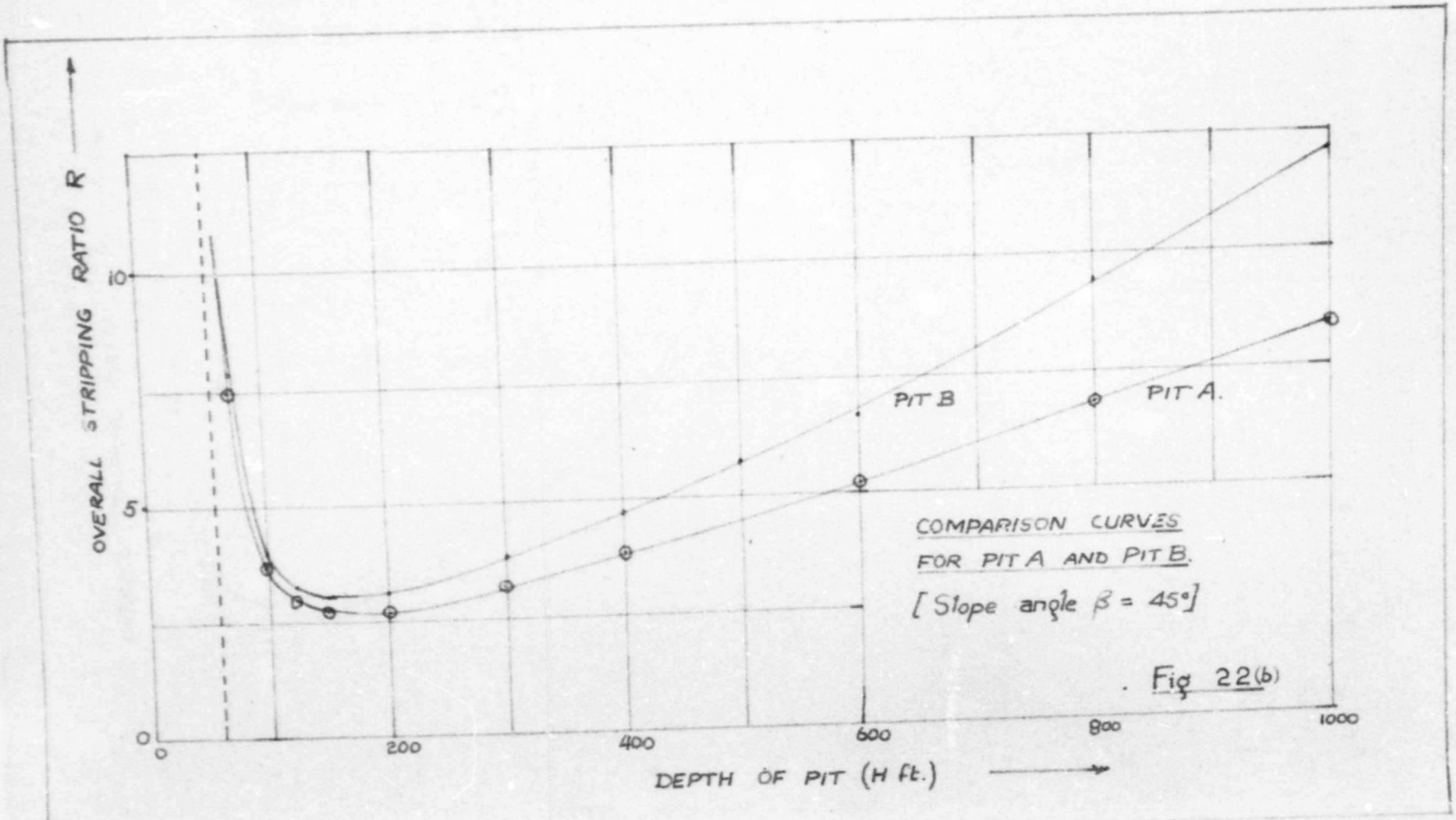

OVERALL STRIPPING RATIO R
10
5
0
0
200
400
600
800
1000
DEPTH OF PIT (H ft.)
PIT B
PIT A.
COMPARISON CURVES
FOR PIT A AND PIT B.
[Slope angle β = 45°]

Fig 22(b)

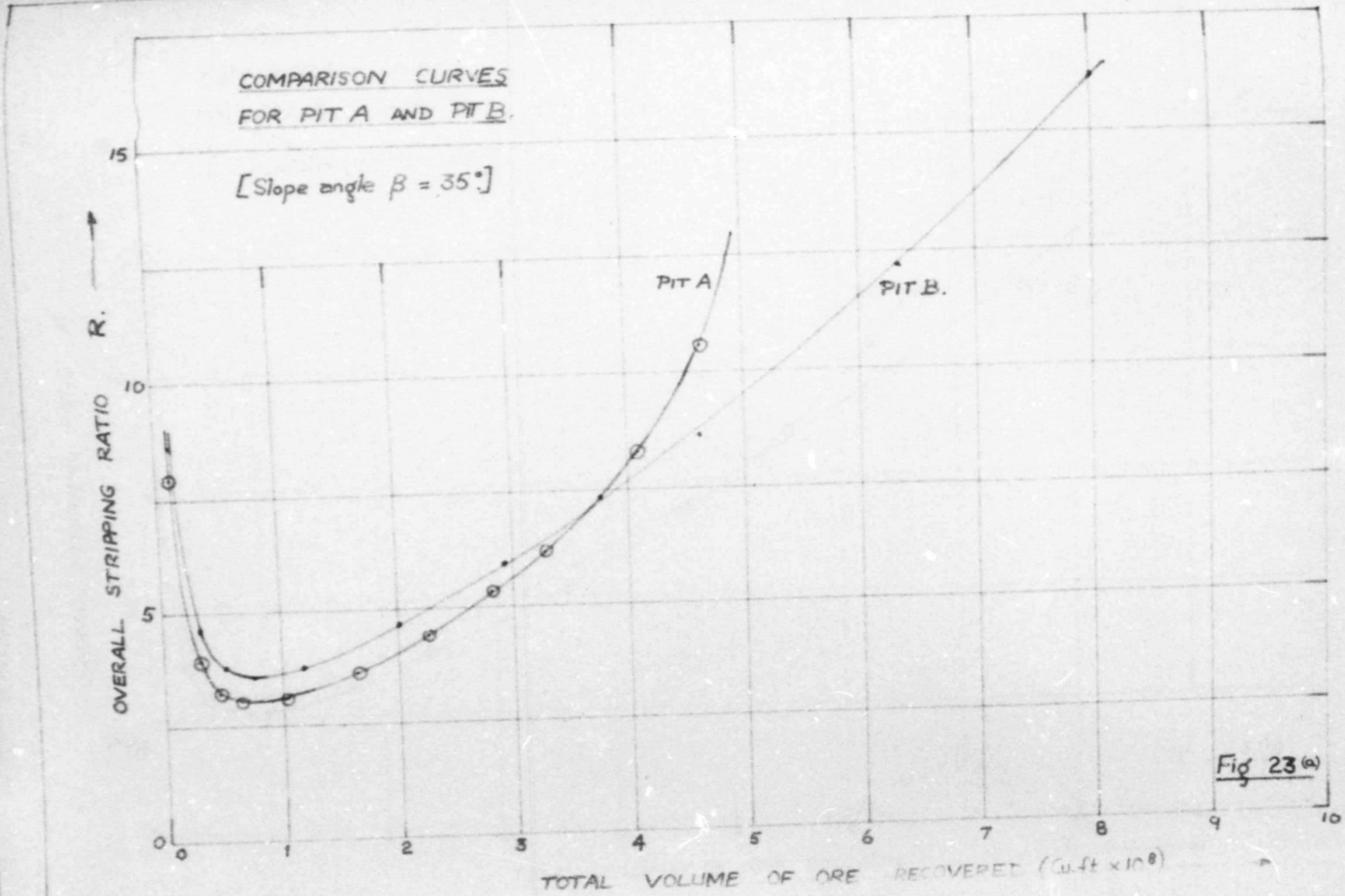

COMPARISON CURVES
FOR PIT A AND PIT B.
[Slope angle β = 35°]
PIT A
PIT B.
OVERALL STRIPPING RATIO R.
TOTAL VOLUME OF ORE RECOVERED (Cu.ft x 10⁸)
0
5
10
15
0
1
2
3
4
5
6
7
8
9
10

Fig 23(a)

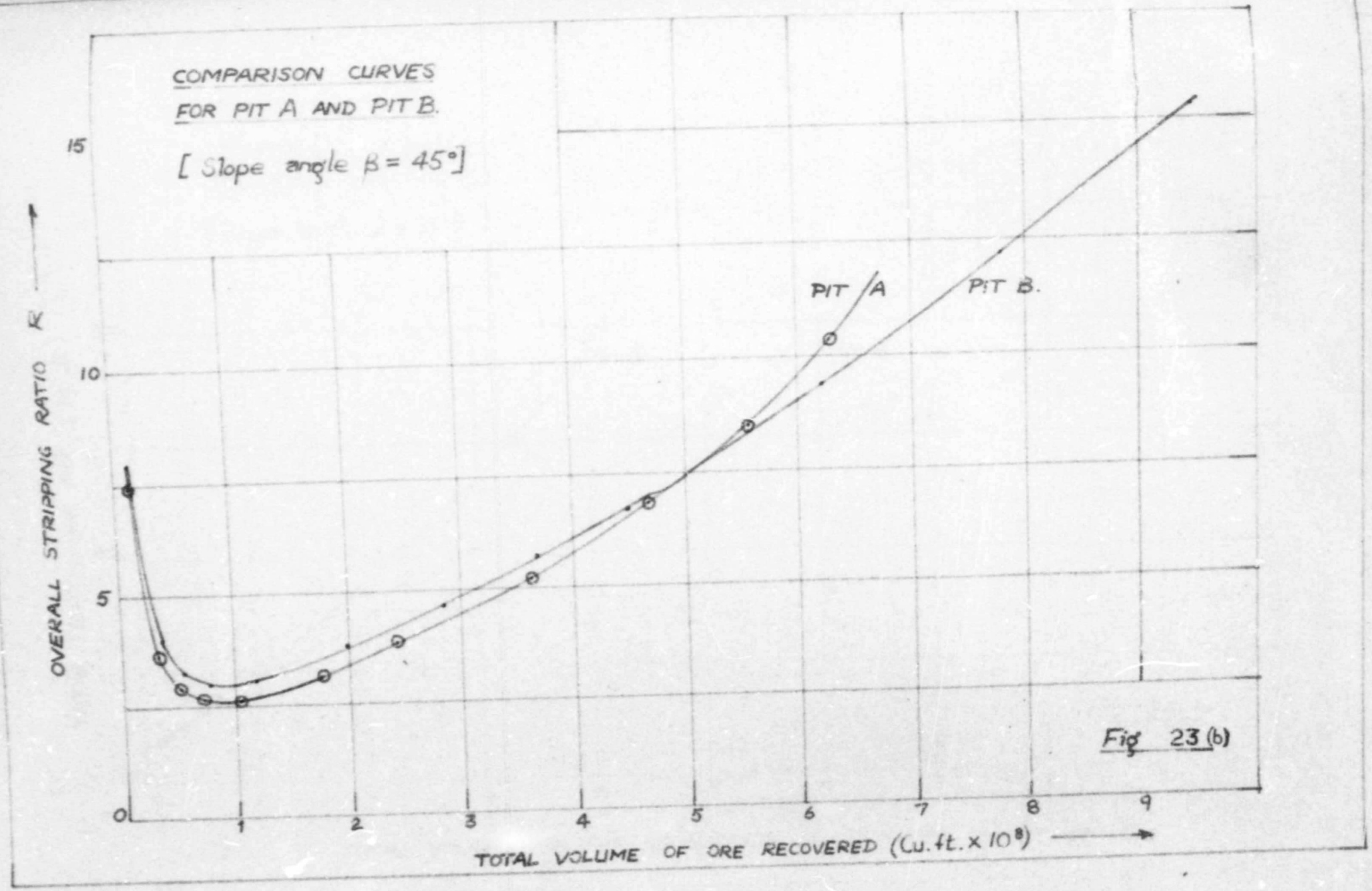

COMPARISON CURVES
FOR PIT A AND PIT B.
[Slope angle β = 45°]
PIT A
PIT B.
OVERALL STRIPPING RATIO K
TOTAL VOLUME OF ORE RECOVERED (Cu. ft. x 10⁸)
0
5
10
15
1
2
3
4
5
6
7
8
9

Fig 23 (b)

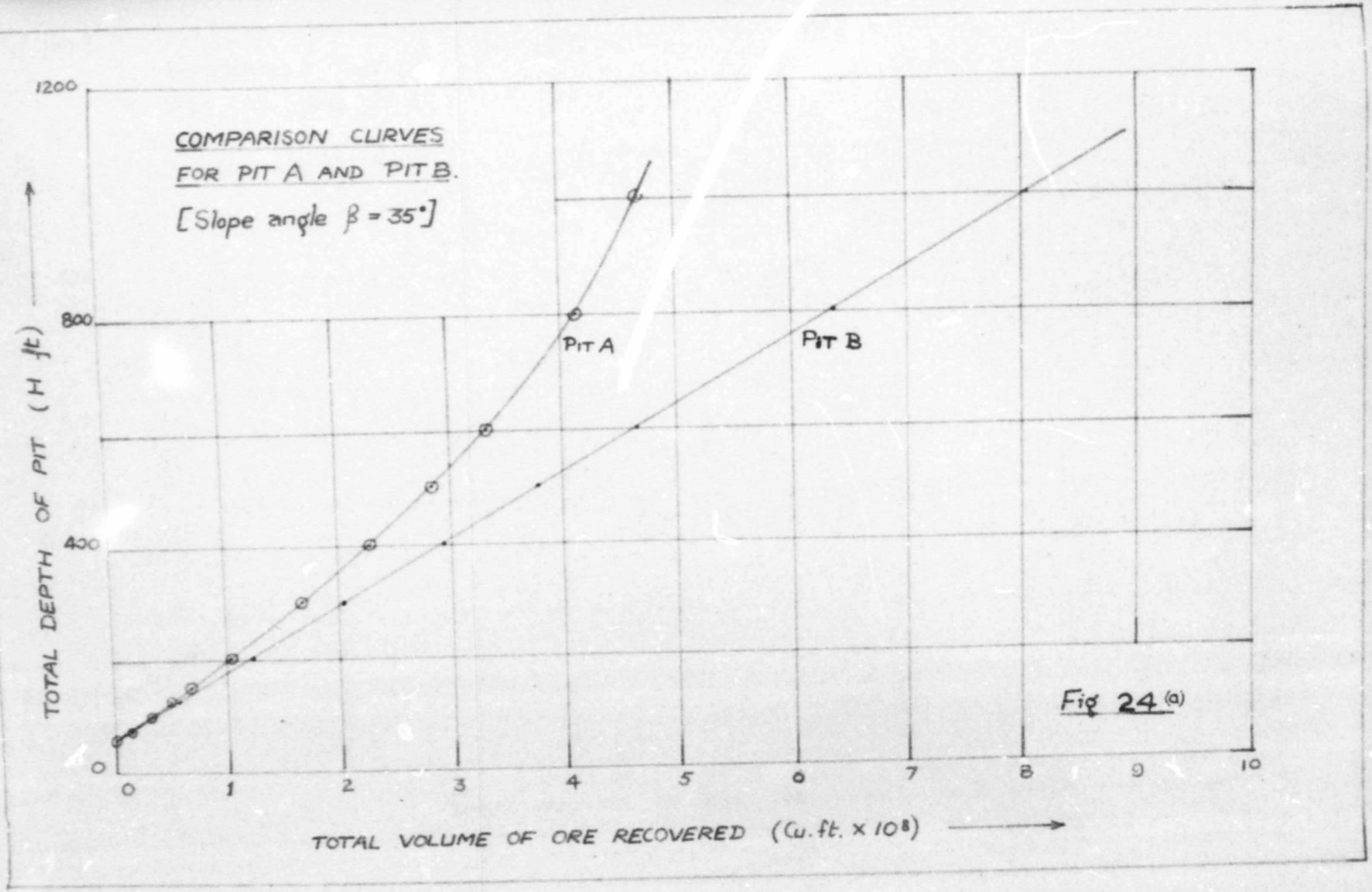

COMPARISON CURVES
FOR PIT A AND PIT B.
[Slope angle β = 35°]
PIT A
PIT B
TOTAL DEPTH OF PIT (H ft)
TOTAL VOLUME OF ORE RECOVERED (Cu. ft. × 10⁸)
1200
800
400
0
0
1
2
3
4
5
6
7
8
9
10

Fig 24 (a)

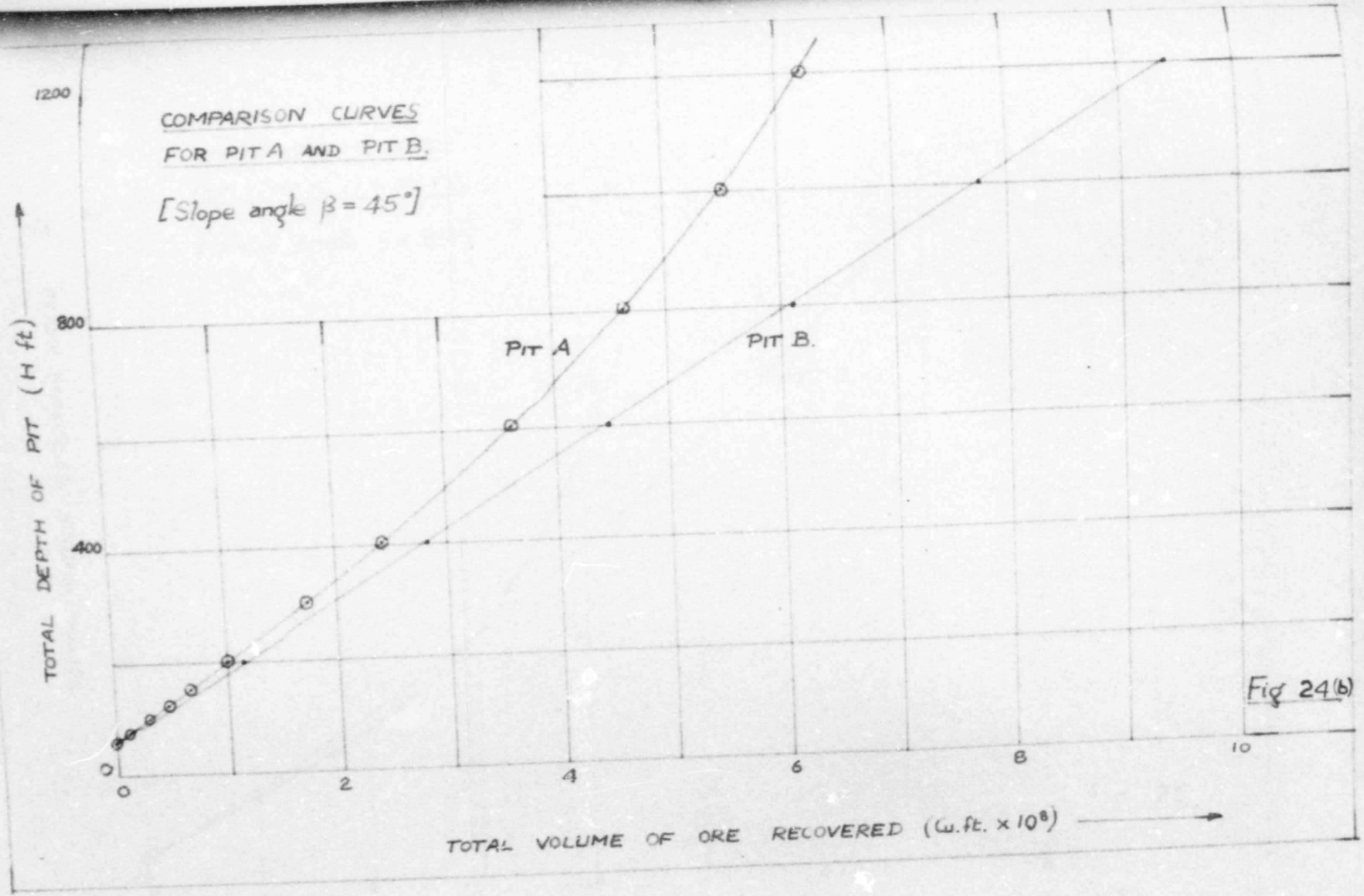

COMPARISON CURVES
FOR PIT A AND PIT B.
[Slope angle β = 45°]
1200
800
400
0
PIT A
PIT B.
TOTAL DEPTH OF PIT (H ft)
0
2
4
6
8
10
TOTAL VOLUME OF ORE RECOVERED (cu.ft. x 10⁸)

Fig 24(b)

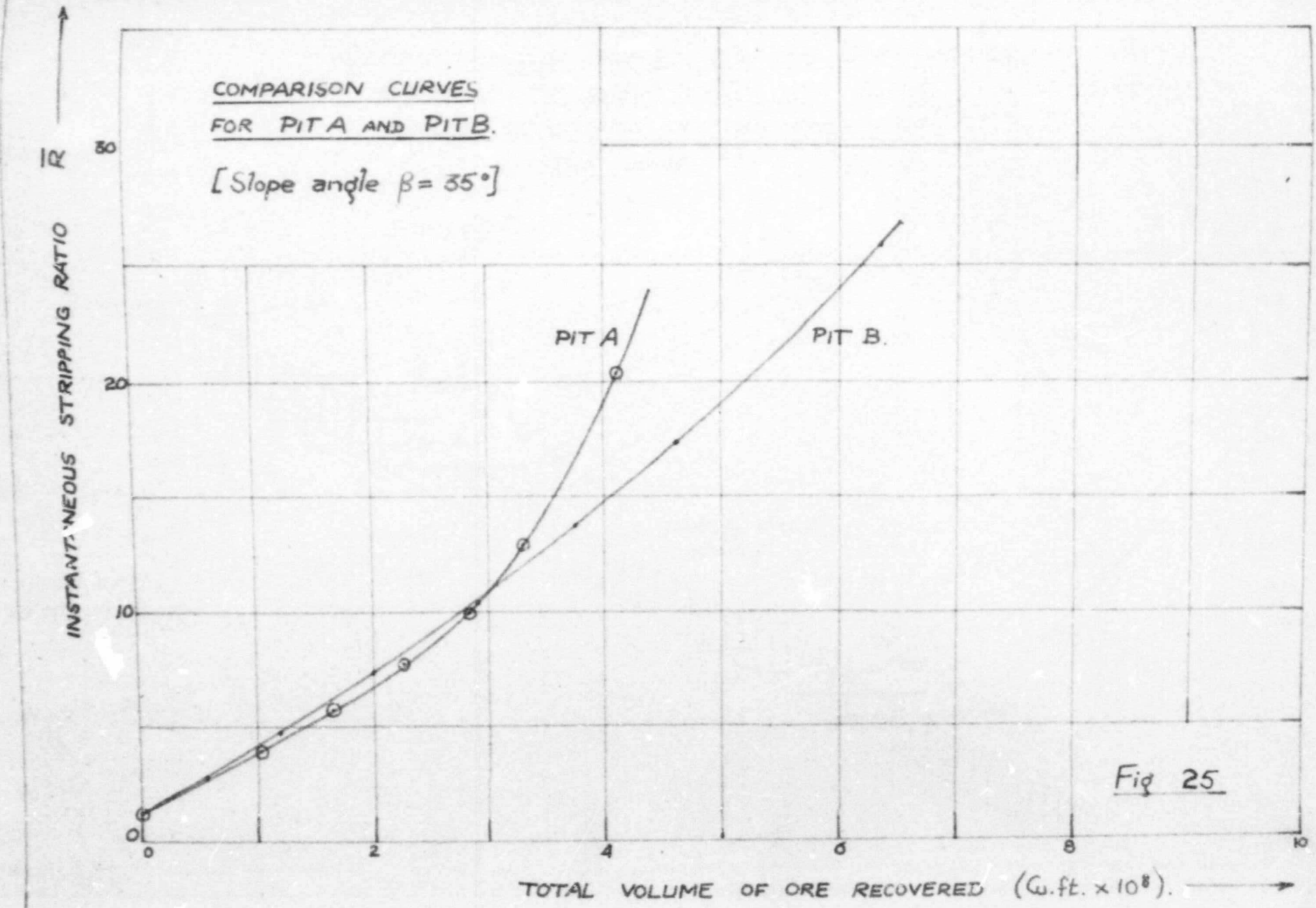

COMPARISON CURVES
FOR PIT A AND PIT B.
[Slope angle β = 35°]
IR
INSTANTANEOUS STRIPPING RATIO
30
20
10
0
PIT A
PIT B.
0
2
4
6
8
10
TOTAL VOLUME OF ORE RECOVERED (Cu.ft. × 10⁸).

Fig 25

SECTION THROUGH PIT B SHOWING HYPOTHETICAL EXAMPLE OF VARIATION OF PIT SLOPE ANGLES DEPENDING ON THE POLICY OF THE MINE.

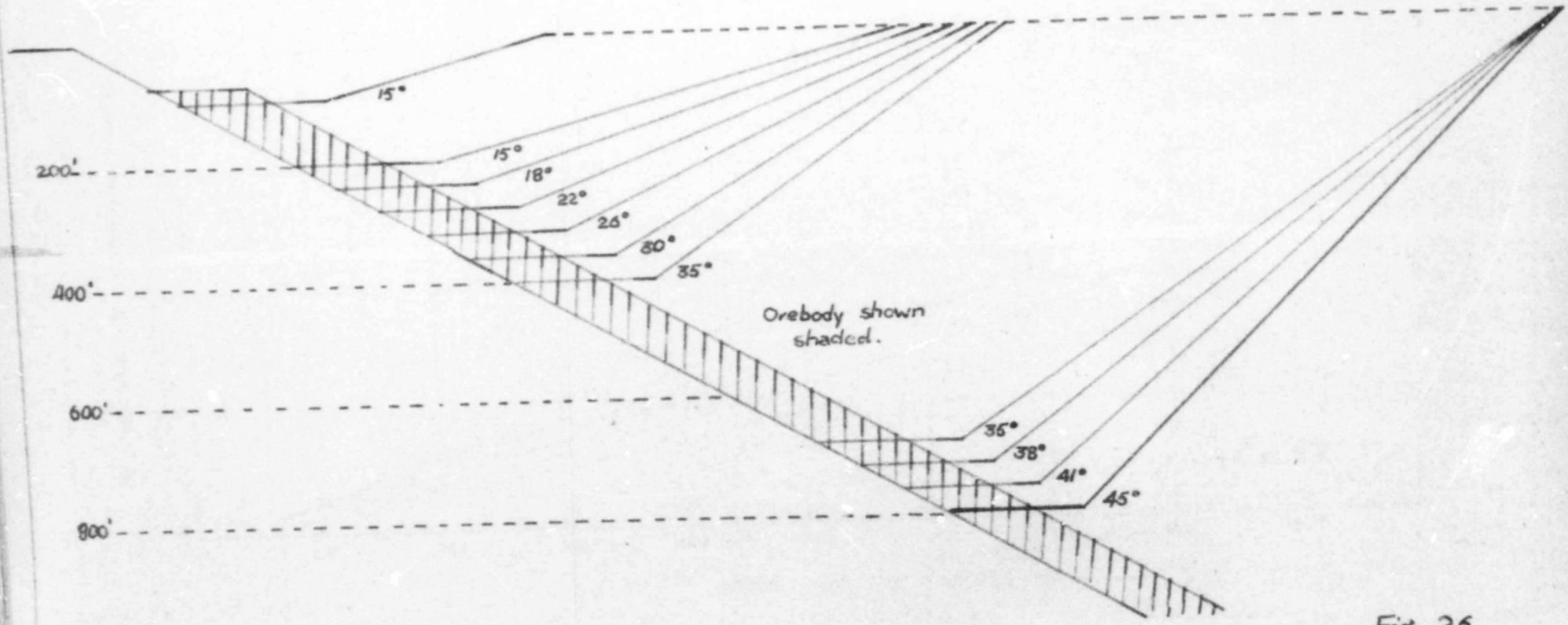


Fig 26

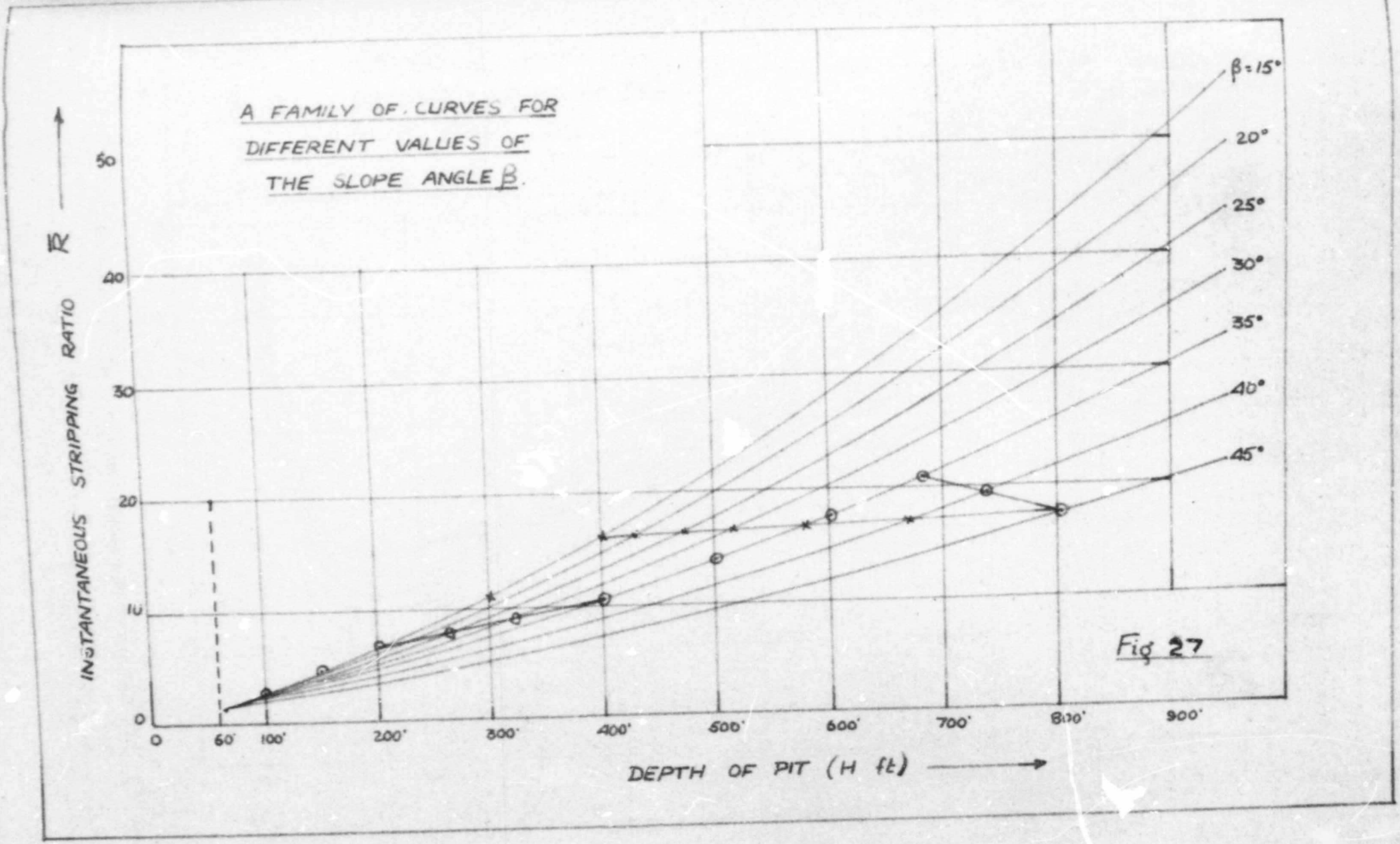
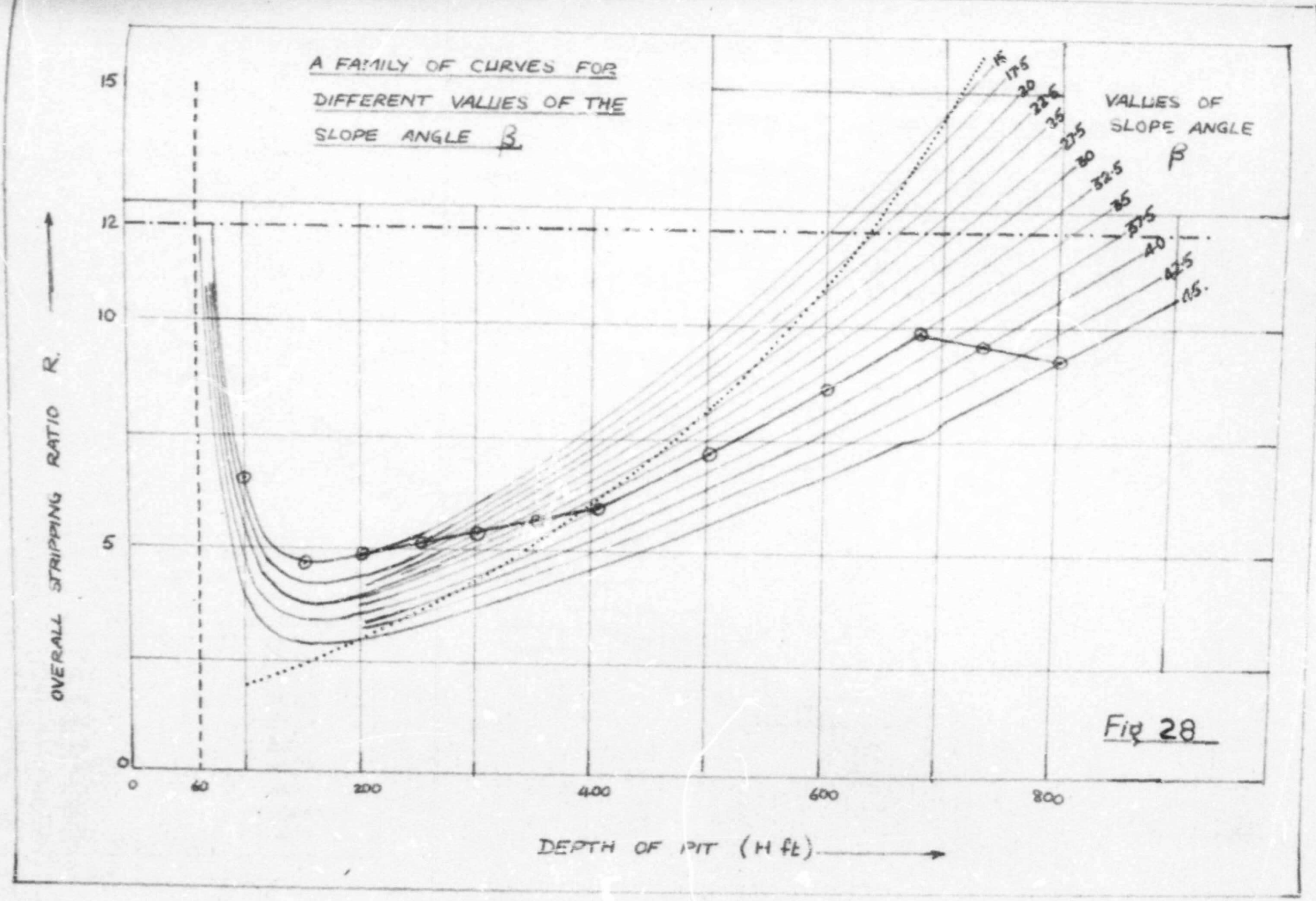
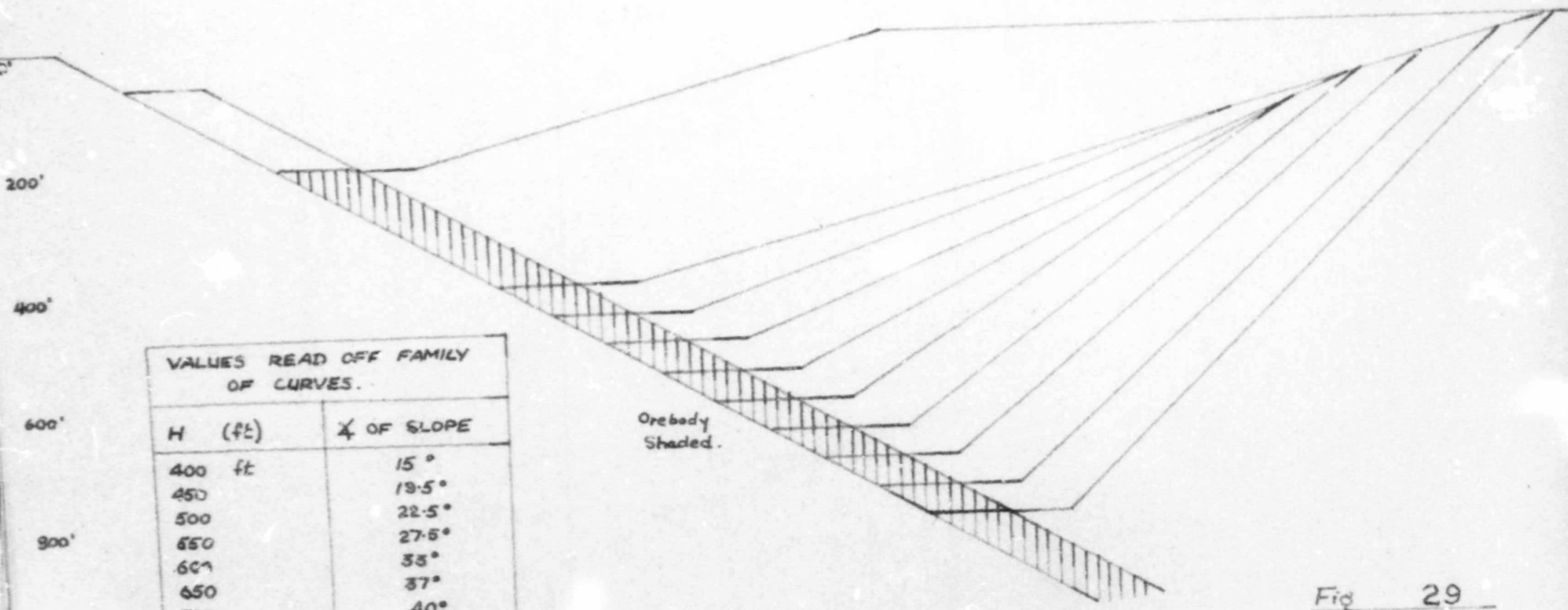

A FAMILY OF CURVES FOR DIFFERENT VALUES OF THE SLOPE ANGLE β.
INSTANTANEOUS STRIPPING RATIO R
DEPTH OF PIT (H ft)
β = 15°
20°
25°
30°
35°
40°
45°
0
10
20
30
40
50
60'
100'
200'
300'
400'
500'
600'
700'
800'
900'

Fig 27


A FAMILY OF CURVES FOR DIFFERENT VALUES OF THE SLOPE ANGLE β
VALUES OF SLOPE ANGLE β
15
17·5
20
22·5
25
27·5
30
32·5
35
37·5
40
42·5
45.
OVERALL STRIPPING RATIO R.
15
12
10
5
0
0
60
200
400
600
800
DEPTH OF PIT (H ft)
Fig 28

SECTION SHOWING PIT PLANNED TO HAVE A FINAL SLOPE OF 45° AT 800 ft, HAVING A FLAT-DIPPING INSTANTANEOUS STRIPPING RATIO CHARACTERISTIC FROM AS EARLY A STAGE AS POSSIBLE.



VALUES READ OFF FAMILY OF CURVES.	
H (ft)	% OF SLOPE
400 ft	15°
450	19·5°
500	22·5°
550	27·5°
600	35°
650	37°
700	40°
750	42·5°
800	45°

Fig 29

Author Brink David Charles
Name of thesis The Stability Of Slopes In Open Cast Mines And The Economic Implications Thereof. 1962

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