

BENCH BLASTING

Comparison between small and large diameter
drill holes, different spacing and various
explosives.

A. Ladegaard-Pedersen

DS 1973: 19

22.10.1973

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Summary.

This report gives a comparison of costs and fragmentation size for a number of different blasting agents and hole size, and further conditions typically valid for a quarry with 10 meter benches. Since the conditions vary considerably from quarry to quarry these calculations do not cover all cases of practical interest.

This work is part of a course in rock blasting technique at the Royal Institute of Technology, Stockholm.

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Basic data

- 1) Bench height: 10 metres
- 2) Rock type: Granite
- 3) Blasting at three free faces (dislocation of rock along one bottom face and one side face)
- 4) No special requirement is considered with regard to fragmentation as the rock is transported to dump area.
- 5) Mucking is done after each round.
- 6) No consideration required as to ground vibrations and throw.
- 7) Short delay detonators to be used.

This comparison refers to the following drill hole diameters:

2", 2½", 3", 3½", 4", 4½", 5" and 6 " and the following alternatives of explosives:

Bottom charge	Column charge	Charge distribution	Specific charge kg/cu.m	
			bottom portion	whole round
Dynamex B	Dynamex B	$l_p = l_b$ (kg/m)	0.42	0.42
Dynamex B	Nabit	$l_p = 0.71 l_b$	0.42	0.34-0.42
Dynamex B	Prillit	$l_p = 0.61 l_b$	0.42	0.34-0.42
Reolit A10	Reolit A10	$l_p = l_b$	0.42	0.42
Reolit A10	Reolit 10-20	$l_p = 0.68 l_b$	0.42	0.34-0.39
Reolit A10	Prillit	$l_p = 0.47 l_b$	0.42	0.28-0.40
Prillit	Prillit	$l_p = l_b$	0.42	0.42

Constants related to the calculation:

Slope of holes	3:1
Rock constant	0.45
E/V	1.3 and 4
Positioning error	0.01 m
Slope deviation	0.02 m/m
Number of hole rows	5
Bench height	10 m

Basic assumptions

Assumptions of comparable costs and prices are made:

<u>Explosives</u>			
Explosives	Price/kg Sw.Crs.	Weight strength (Ref. Dynamex)	Rate of density (kg/litre in hole)
Dynamex B	2:90	1	1.25
Reolit A10	2:20	1.08	1.5
Prillit	0:85	0.85	0.9
Reolit 10	1:35	0.72	1.5
Reolit 20	1:60	0.73	1.5
Nabit	2:00	0.89	1.0

Cost of ignition of Dynamex charged rounds 1:50 Crs/hole

" " " " other " 3:50 Crs/hole

Description of explosives.

Dynamex	Plastic dynamite of high density, in paper or plastic bags.
Reolit A10	Aluminized slurry of high density, the sensitivity of which has been increased by TNT-additive. Contents of Aluminum = 15 %.
Reolit 10	TNT-slurry of high density ($> 3''$)
Reolit 20	TNT-slurry of high density ($2''$ to $2\frac{1}{2}''$)
Nabit	Powder-dynamite of low density, in paper, plastic bags or plastic pipes.
Prillit	Fine grain ammonium nitrate explosives, easy flowing type.

Drilling cost: see graph 2.

Conclusions:

- 1) A constant specific charge at a round with small diameter drill-holes the fragmentation of rock is better than that obtained in the case of large diameter holes.
- 2) The total cost of drilling + explosives becomes lower when increasing the hole diameter.
- 3) A combination of heavy bottom charge of Reolit A 10 and cheap ammonium nitrate explosives as column charge gives the lowest total cost per cu.m. of rock within the range of diameter 2" to 5".
- 4) The total cost for drilling and explosives is slightly lower at the Prillit case than that of Reolit when diameters $\geq$ 5" are chosen.
- 5) As the Prillit case leads to a more than doubling of the number of drillholes for the same rock volume as the case of Reolit, this means loss of capacity and increased investment requirements.

General aspects:

- 6) Limiting factors for the use of Prillit is mainly water in drill-holes, and that detonators and the like have to be inserted in the holes simultaneously as the explosives. When applying Reolit this (primer + detonator) can be introduced into the charged hole in the desired moment.
- 7) The risk of throw increases in relation to larger drillholes.
- 8) The cracking below the theoretical contour increases in relation to larger drillholes.
- 9) The basis for required capacity and improved economy often relates to large hole diameters.

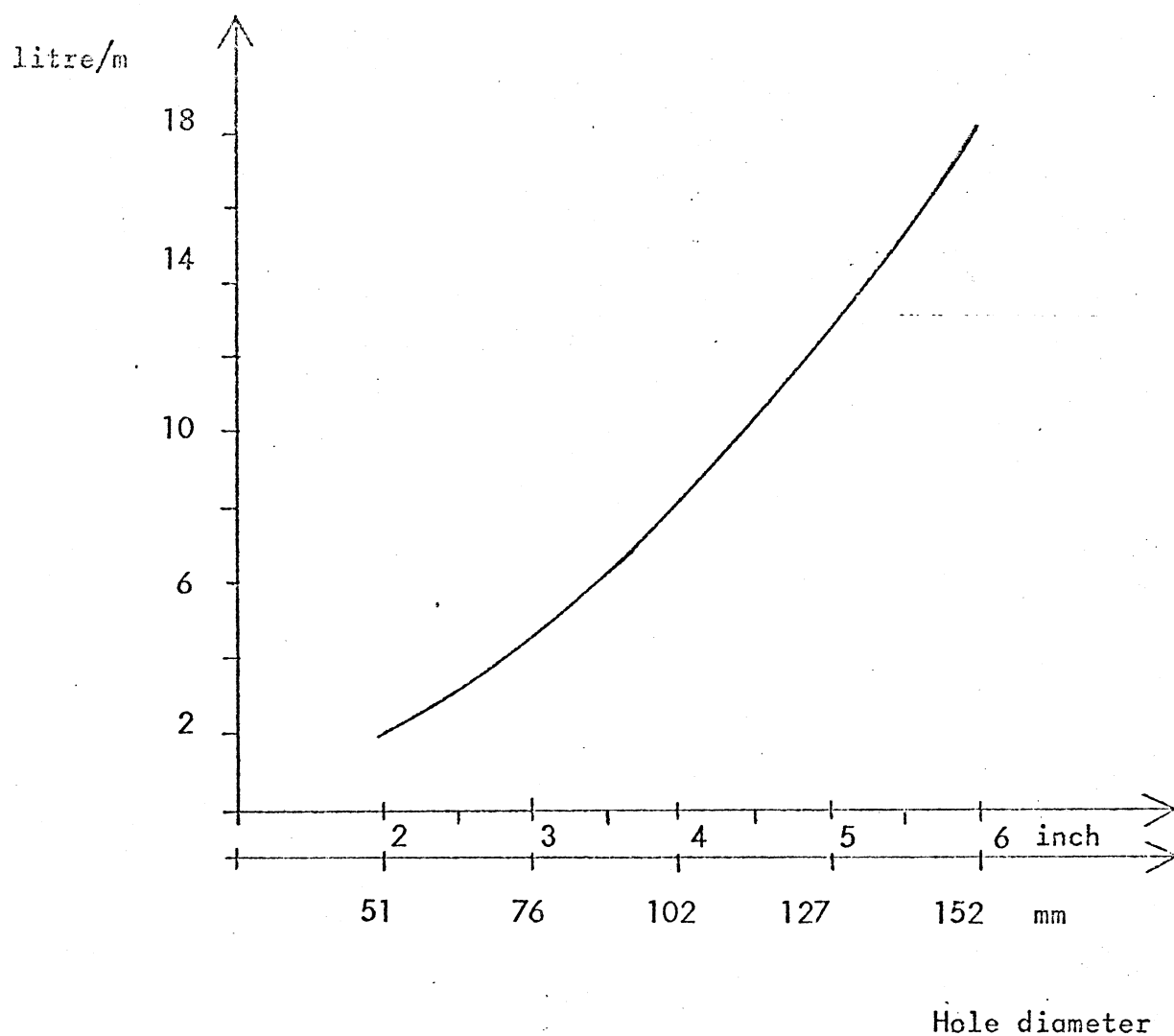
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Denomination:

d	hole diameter	mm or inch
H	hole length	m
V_l	practical burden	m
E_l	practical spacing	m
Q_b	bottom charge	kg
Q_p	column charge	kg
Q_T	total charge	kg
l_b	concentration of charge in bottom	kg/m
l_p	concentration of charge in column	kg/m
q	specific charge	DxB/cu.m.

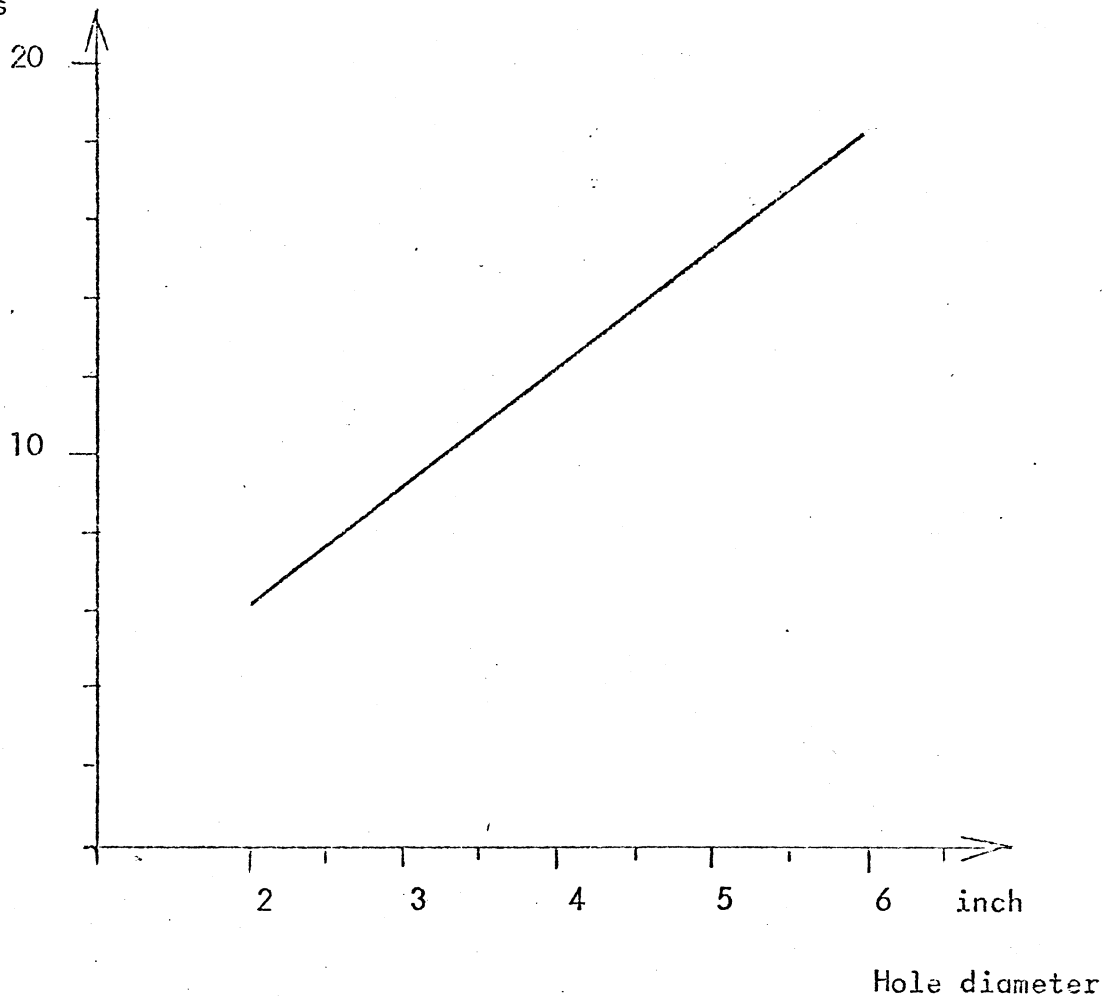
Volume per metre of hole



Graph 1. Drilled hole volume per metre of drillhole at different hole diameters.

Cost per metre
of drillhole

SwCrs



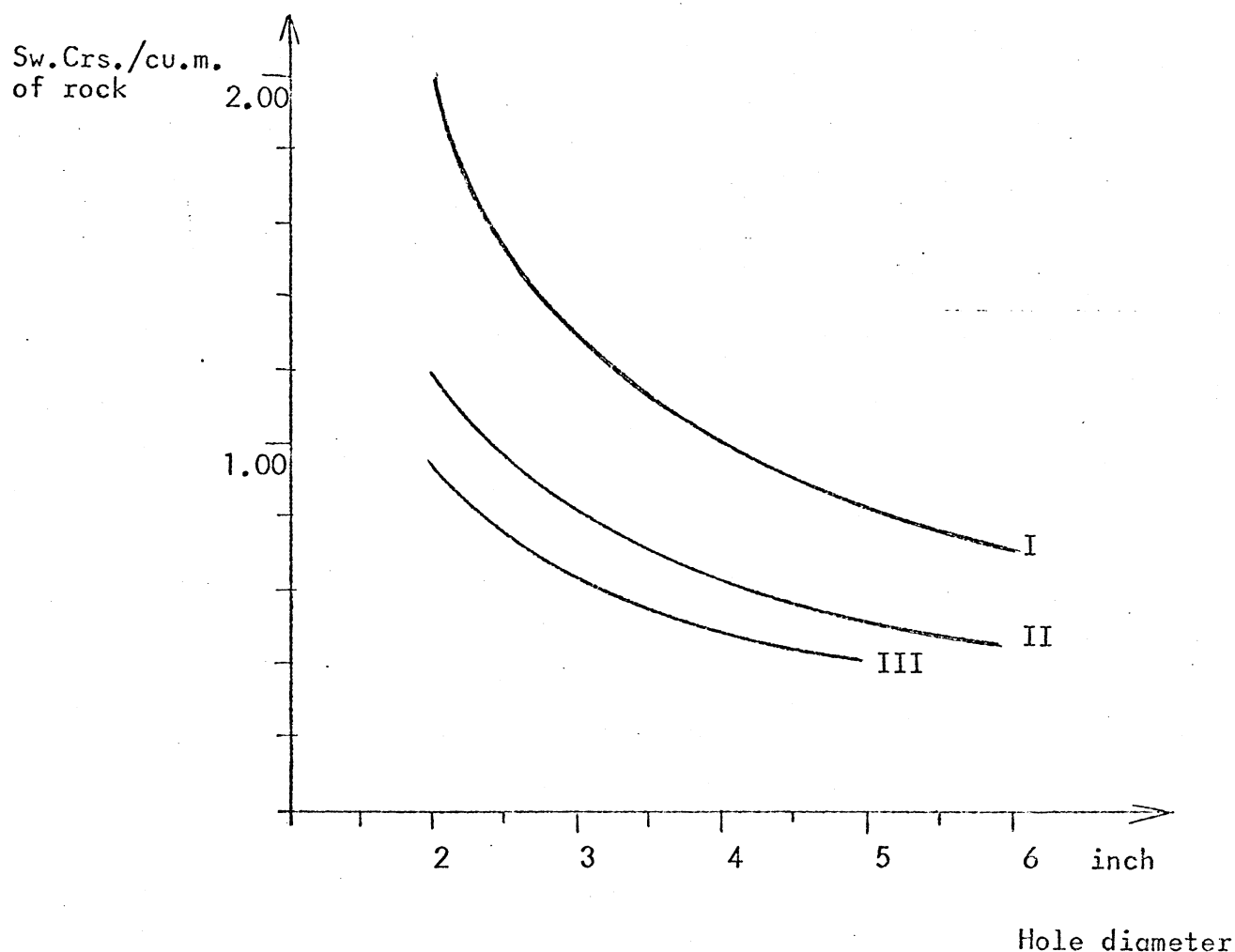
Graph 2. Drilling costs per metre of drill hole as a function of the hole diameter.

The costs refer to approximated intelligent guesses and serve as basis for the calculations of the present study. As the prevailing conditions at different quarries vary, pretention on absolute correctness is not possible.

The cost per cu.m. is obtained by multiplying the cost per metre of drilling by the specific drilling.

The cost comprises invested capital, wages, drill steel, grinding, compressed air, reparation, spare parts and other running costs. The drilling equipment for different hole diameters vary in type, however, but range same technical level of development.

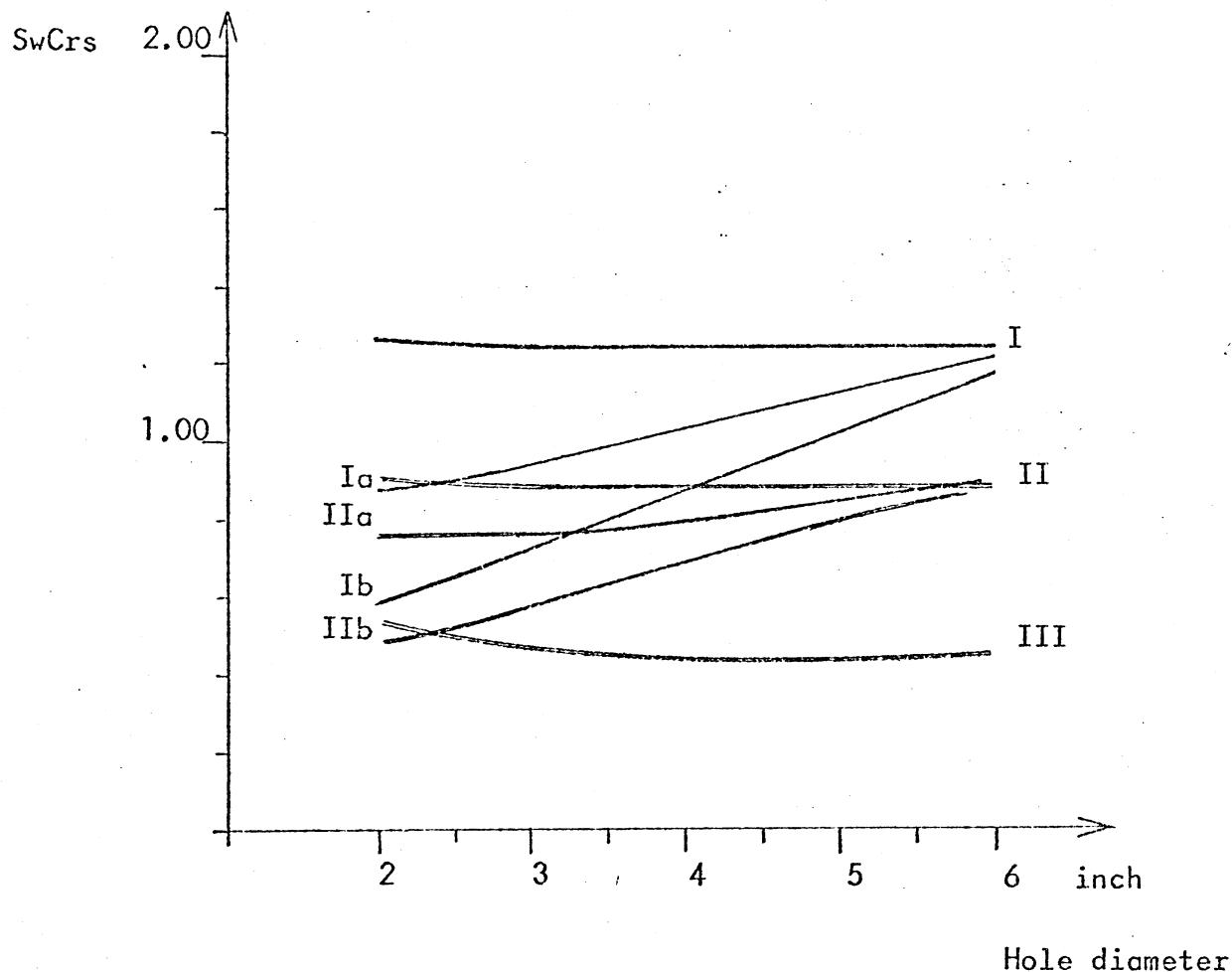
Drilling cost per cu.m. of rock



- I Prillit
 II Dynamex B at constant specific charge
 III Reolit corresponding to 0.42 kg DxB/cu.m.

Graph 3. The cost of drilling per cu.m. of rock as function of the hole diameter related to different explosives. The graph indicates that the drilling cost decreases at increased hole diameter. For instance, the drilling cost for Prillit is more than the double of that for Reolit A10. In the case the degree of packing of Dynamex B (here chosen as 1.25 kg/litre) is being increased, a lower cost of drilling is achieved.

Cost of explosives (including detonators) per cu.m. of rock

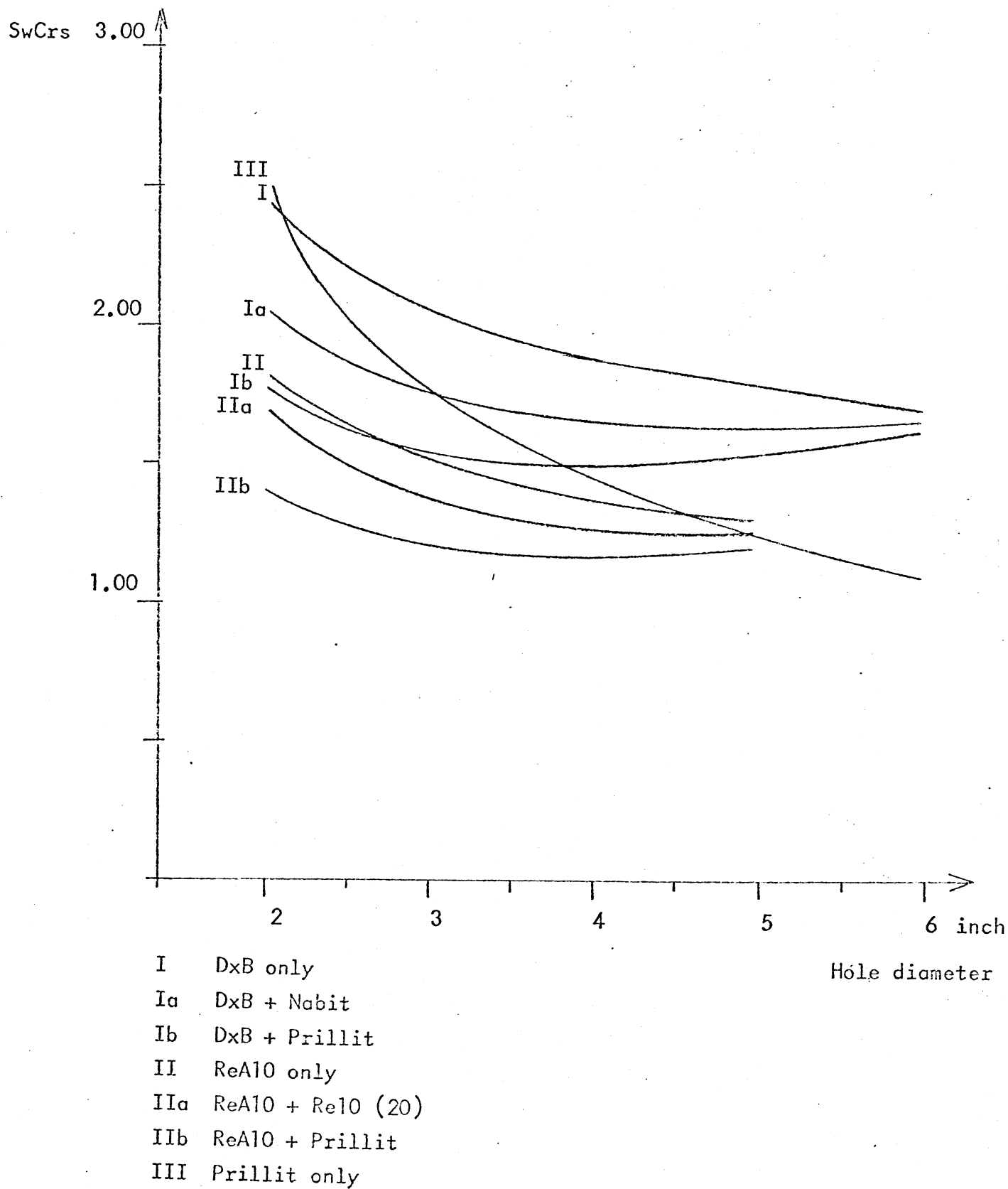


- I DxB only
- Ia DxB + Nabit
- Ib DxB + Prillit
- II ReA10 only
- IIa ReA10 + Re10 (20)
- IIb ReA10 + Prillit
- III Prillit only

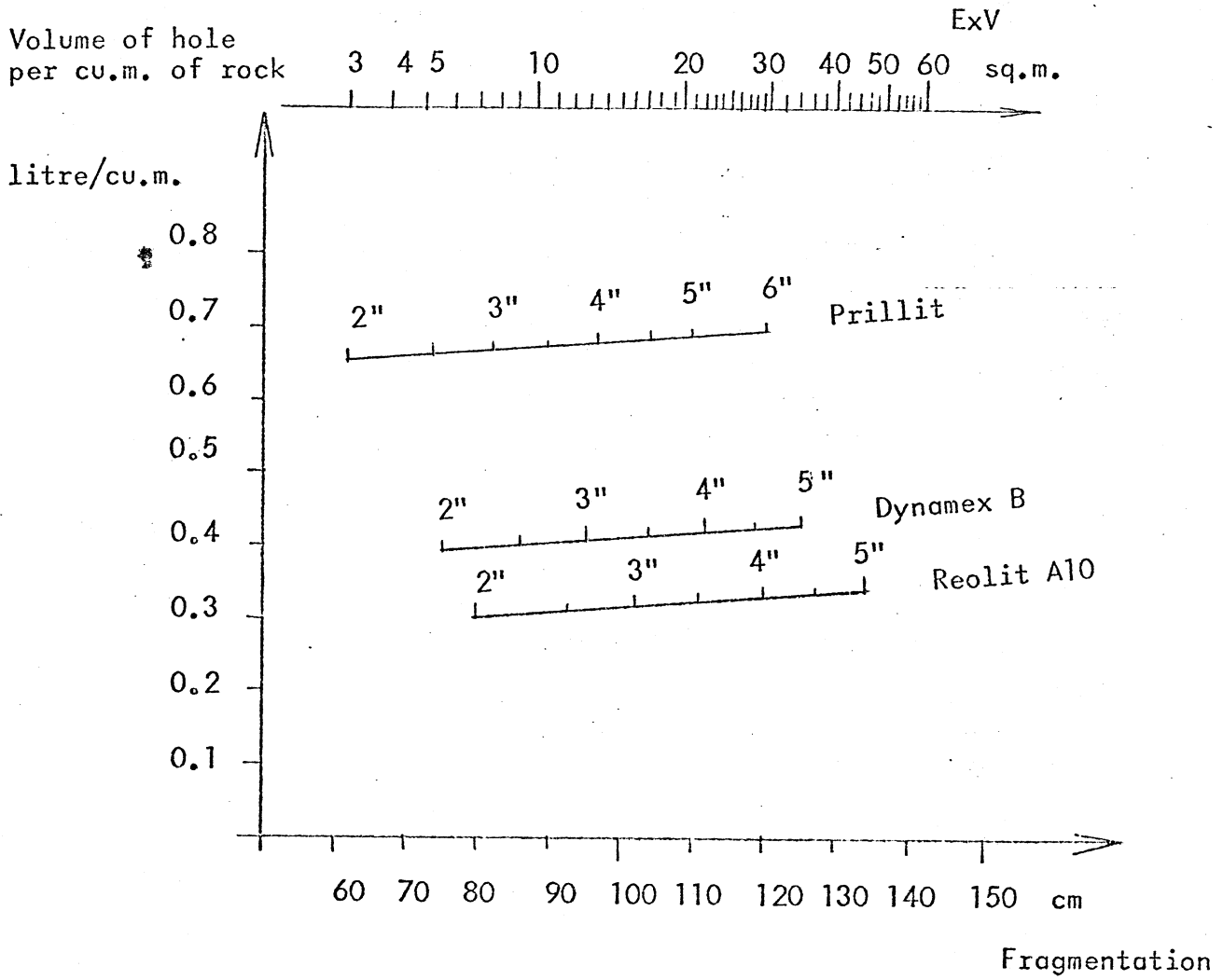
Graph 4. Cost of explosives per cu.m. of rock as function of the hole diameter.

The graph does not include costs for charging and blasting, which decrease at increased hole diameter.

Cost of drilling + explosives (incl. detonators etc.) per cu.m. of rock

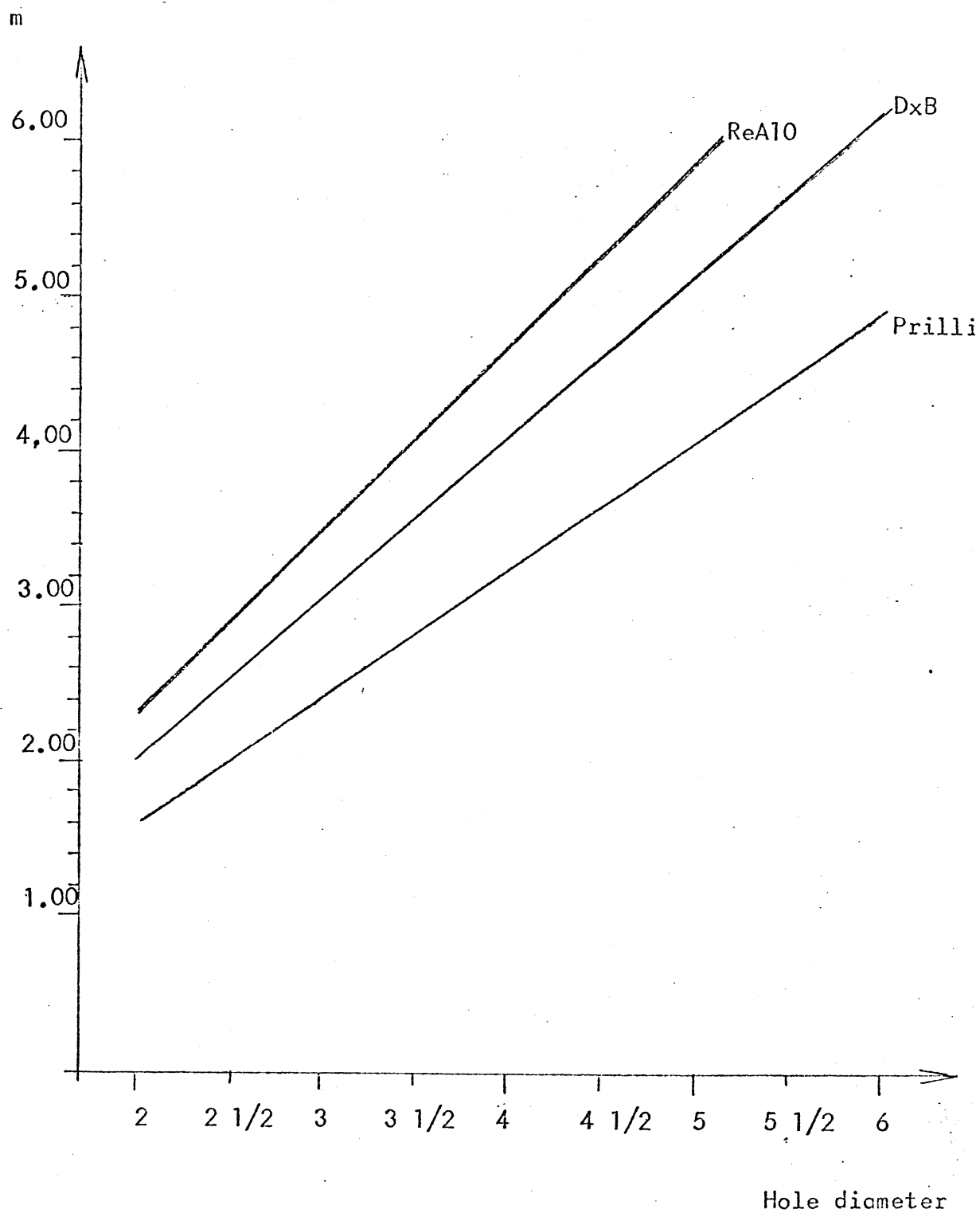


Graph 5. Total cost of drilling + explosives at different drillhole diameters.



Graph 6. Drillhole volume as function of degree of fragmentation at constant specific charge (0.42 kg DxB/cu.m. of rock) and different explosives.

PRACTICAL BURDEN V



Graph 7. Practical burden V related to different drillhole diameters.

DYNAMEX B only

Drilling and charging per hole										Cost per cu.m. of rock		Fragmentation	
d mm	H m	V _L m	E _L m	Q _T kg	l _b kg/m	l _p kg/m	q kg DxB/cu.m.	Drilling SwCrs	Explosive SwCrs	Total SwCrs	E/V = 1.3 m	E/V = 4 m	
51	11.34	2.07	2.69	24.8	2.55	2.55	0.42	1.18	1.25	2.43	0.75	0.64	
64	11.52	2.60	3.38	39.0	4.02	4.02	0.42	0.96	1.24	2.20	0.86	0.73	
76	11.69	3.09	4.01	55.1	5.67	5.67	0.42	0.81	1.24	2.05	0.95	0.81	
89	11.87	3.62	4.70	75.8	7.78	7.78	0.42	0.71	1.24	1.95	1.04	0.88	
102	12.05	4.14	5.39	100.0	10.21	10.21	0.42	0.63	1.24	1.87	1.12	0.95	
115	12.23	4.67	6.07	127.6	12.98	12.98	0.42	0.56	1.24	1.80	1.19	1.01	
127	12.40	5.16	6.71	142.3	15.83	15.83	0.42	0.52	1.24	1.76	1.24	1.14	
152	12.75	6.17	8.03	219.1	22.68	22.68	0.42	0.44	1.24	1.68	1.43	1.21	

DYNAMEX + NABIT

Drilling and charging per hole										Cost per cu.m. of solid rock			Fragmentatic
d	H	V _L	E _L	Q _b	Q _p	l _b	l _p	q	Drilling	Explosive	Total	E/V = 1.3 E/V _m	
mm	m	m	m	kg	kg	kg/m	kg/m	kg DxB/cu.m.	SwCrs	SwCrs	SwCrs	m	
51	11.34	2.07 1.18	2.69 4.72	7.9	13.53	2.55	2.04	0.34	1.18	0.86	2.04	0.98	
64	11.52	2.60 1.48	3.38 5.93	15.5	18.78	4.02	3.21	0.35	0.95	0.90	1.86	1.08	
76	11.69	3.09 1.76	4.01 7.04	26.0	23.27	5.67	4.52	0.36	0.81	0.92	1.73	1.15	
89	11.87	3.62 2.06	4.70 8.24	41.7	27.22	7.78	6.20	0.37	0.71	0.98	1.69	1.22	
102	12.05	4.14 2.36	4.39 9.45	62.7	29.68	10.21	8.15	0.38	0.63	1.03	1.66	1.28	
115	12.23	4.67 2.66	6.07 10.65	90.0	30.10	12.98	10.36	0.39	0.56	1.08	1.64	1.32	
127	12.40	5.16 2.94	6.71 11.76	121.1	28.21	15.83	12.63	0.40	0.52	1.12	1.64	1.36	
152	12.75	6.17 3.52	8.03 14.08	207.6	15.33	22.68	18.09	0.42	0.44	1.21	1.65	1.43	
												1.2	

Table 3.

DYNAMEX + PRILLIT

Drilling and charging per hole										Cost per cu.m. of solid rock			Fragmentation
d mm	H m	V ₁ m	E ₁ m	Q _b kg	Q _p kg	l _b kg/m	l _p kg/m	q kg DxB/cu.m.	Drilling SwCrs	Explosive SwCrs	Total SwCrs	E/V=1.3 m	E/V=4
													m
51	11.34	2.07 1.18	2.70 4.73	7.9	12.2	2.55	1.83	0.31	1.18	0.59	1.77	1.09	0.92
64	11.52	2.60 1.48	3.38 5.93	15.5	16.9	4.02	2.88	0.32	0.96	0.66	1.62	1.18	1.00
76	11.69	3.09 1.76	4.01 7.04	26.0	20.9	5.67	4.05	0.33	0.81	0.72	1.53	1.25	1.06
89	11.87	3.62 2.06	4.70 8.24	41.7	24.5	7.78	5.57	0.35	0.71	0.80	1.51	1.30	1.11
102	12.05	4.14 2.36	5.39 9.45	62.7	26.7	10.21	7.32	0.36	0.63	0.88	1.51	1.34	1.14
115	12.23	4.67 2.66	6.07 10.65	90.0	27.1	12.98	9.30	0.38	0.56	0.96	1.52	1.38	1.17
127	12.40	5.16 2.94	6.71 11.76	121.1	11.4	15.83	11.35	0.39	0.52	0.99	1.51	1.40	1.19
152	12.75	6.17 3.52	8.03 14.08	207.6	16.3	22.68	16.28	0.42	0.44	1.18	1.62	1.43	1.21

Table 4.

REOLIT A10 only

Drilling and charging per hole							Cost per cu.m. of solid rock			Fragmentation		
d	H	V _L	E _L	Q _T	L _b	L _p	q	Drilling	Explosive	Total	E/V = 1.3	E/V = 4
mm	m	m	m	kg	kg/m	kg/m	kg DxB/cu.m.	SwCrs	SwCrs	SwCrs	m	m
51	11.44	2.36	3.07	29.74	3.06	3.06	0.42	0.92	0.90	1.82	0.81	0.69
		1.34	5.38									
64	11.65	2.96	3.85	46.88	4.83	4.83	0.42	0.75	0.89	1.64	0.93	0.79
		1.69	6.75									
76	11.84	3.51	4.57	66.28	6.80	6.80	0.42	0.63	0.88	1.51	1.02	0.87
		2.00	8.01									
89	12.04	4.12	5.35	91.28	9.33	9.33	0.42	0.55	0.88	1.43	1.11	0.95
		2.35	9.38									
102	12.25	4.72	6.13	120.54	12.25	12.26	0.42	0.49	0.88	1.37	1.20	1.02
		2.69	10.76									
115	12.45	5.32	6.91	154.19	15.58	15.58	0.42	0.44	0.88	1.32	1.27	1.08
		3.03	12.13									
127	12.64	5.87	7.63	189.27	19.00	19.00	0.42	0.41	0.88	1.29	1.34	1.14
		3.35	13.39									

Table 5.

REOLIT A10 + REOLIT 10 AND 20

Drilling and charging per hole				Cost per cu.m. of solid rock				Fragmentation					
d mm	H m	V _L m	E _L m	Q _b kg	Q _p kg	I _b kg/m	f _p kg/m	q kg DxB/cu.m.	Drilling SwCrs	Explosive SwCrs	Total SwCrs	E/V=1.3 m	E/V=4 m
51	11.44	2.36 1.34	3.07 5.38	10.7	19.15	3.06	3.06	0.34	0.92	0.76	1.68	1.07	0.90
64	11.65	2.96 1.69	3.85 6.75	21.17	25.8	4.83	4.83	0.35	0.75	0.76	1.51	1.16	0.90
76	11.84	3.51 2.00	4.57 8.01	35.5	30.8	6.80	6.80	0.36	0.63	0.73	1.36	1.16	0.90
89	12.04	4.12 2.35	5.35 9.38	56.9	34.3	9.33	9.33	0.37	0.55	0.75	1.30	1.23	1.00
102	12.25	4.72 2.69	6.13 10.76	85.7	34.8	12.26	12.26	0.37	0.49	0.78	1.27	1.28	1.00
115	12.45	5.32 3.03	6.91 12.13	122.8	31.4	15.58	15.58	0.38	0.44	0.82	1.26	1.32	1.10
127	12.64	5.87 3.35	7.63 13.39	165.4	25.9	19.00	19.00	0.39	0.41	0.85	1.26	1.35	1.10

Table 6.

REOLIT A10 + PRILLIT

d mm	H m	V ₁ m	Drilling and charging per hole				q kg DxB/cu.m.	Cost per cu.m. of solid rock			Fragmentation	
			E ₁ m	Q _b kg	Q _p kg	l _b kg/m	l _p kg/m	Drilling SwCrs	Explosive SwCrs	Total SwCrs	E/V=1.3 m	E/V=4 m
51	11.44	2.36 1.34	3.07 5.38	10.7	11.4	3.06	1.83	0.92	0.48	1.40	1.33	1.13
64	11.65	2.96 1.69	3.85 6.75	21.2	15.4	4.83	2.88	0.75	0.53	1.28	1.39	1.18
76	11.84	3.51 2.00	4.57 8.01	35.5	18.4	6.80	4.06	0.63	0.57	1.20	1.42	1.21
89	12.04	4.12 2.35	5.35 9.38	56.9	20.5	9.33	5.57	0.55	0.63	1.18	1.45	1.23
102	12.25	4.72 2.69	6.13 10.76	85.69	20.8	12.25	7.32	0.49	0.69	1.18	1.46	1.24
115	12.45	5.32 3.03	6.91 12.13	122.8	18.7	15.58	9.30	0.44	0.75	1.19	1.46	1.24
127	12.64	5.87 3.35	7.63 13.39	165.4	14.3	19.00	11.35	0.41	0.80	1.21	1.45	1.23

Table 7.
PRILLIT only

PRILLIT only

Drilling and charging per hole							Cost per cu.m. of solid rock			Fragmentation		
d	H	V _l	E _l	Q _T	l _b	l _p	q	Drilling	Explosive	Total	E/V = 1.3	E/V = 4
mm	m	m	m	kg	kg/m	kg/m	kg DxB/cu.m.	SwCrs	SwCrs	SwCrs	m	m
51	11.17	1.59	2.07	17.9	1.83	1.83	0.42	1.97	0.53	2.50	0.62	0.53
64	11.32	0.91	3.63	28.1	2.88	2.88	0.42	1.54	0.47	2.01	0.74	0.63
76	11.45	2.41	3.14	39.6	4.06	4.06	0.42	1.30	0.46	1.76	0.82	0.70
89	11.59	1.38	5.50	54.3	5.51	5.51	0.42	1.13	0.45	1.58	0.90	0.77
102	11.73	2.83	3.67	71.5	7.32	7.32	0.42	1.00	0.44	1.44	0.97	0.83
115	11.87	1.85	7.39	91.0	9.30	9.30	0.42	0.90	0.44	1.34	1.04	0.88
127	12.00	3.65	4.75	111.3	11.35	11.35	0.42	0.82	0.43	1.25	1.10	0.93
152	12.28	2.08	8.33	160.6	16.28	16.28	0.42	0.70	0.43	1.13	1.21	1.03
178	12.56	4.83	6.28	222.3	22.4	22.4	0.42	0.61	0.43	1.04	1.31	1.11
		2.75	11.01									
		5.65	7.35									
		3.22	12.89									