SSC-N-626
April 1989

Geology and Geotechnical Considerations of the SSC Site in Texas:

Texas TBM Tunneling Experience

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Material Presented at the meeting of the Underground Tunnelling Advisory Panel
April 30, 1989 at the
SSC Laboratory at Lawrence Berkeley Laboratory

MASTER SYMBOL

For marl, marly claystone data only :

- ▫ SAN-ANTONIO RIVER
- ▪ SAN-ANTONIO RIVER WEATHERED
- ■ SAN-PEDRO CREEK
- ▪ SAN-PEDRO CREEK WEATHERED

For marly claystone and chalk data :

- ▲ GOVALLE-LATE-CLAYSTONE
- ▲ GOVALLE-LATE-CHALKY CLAYSTONE
- ▲ GOVALLE-EARLY
- ○ S S C- S. W. L.
- ● S S C- M. J. A.
- × SSC-EARLY
- ◇ ONION CREEK IV
- ◆ ONION CREEK II

For chalk and limestone data :

- ▫ DART-PLANO LINE
- ✖ SLAUGHTER CREEK
- ■ WALLER CREEK
- + BRUSHY CREEK

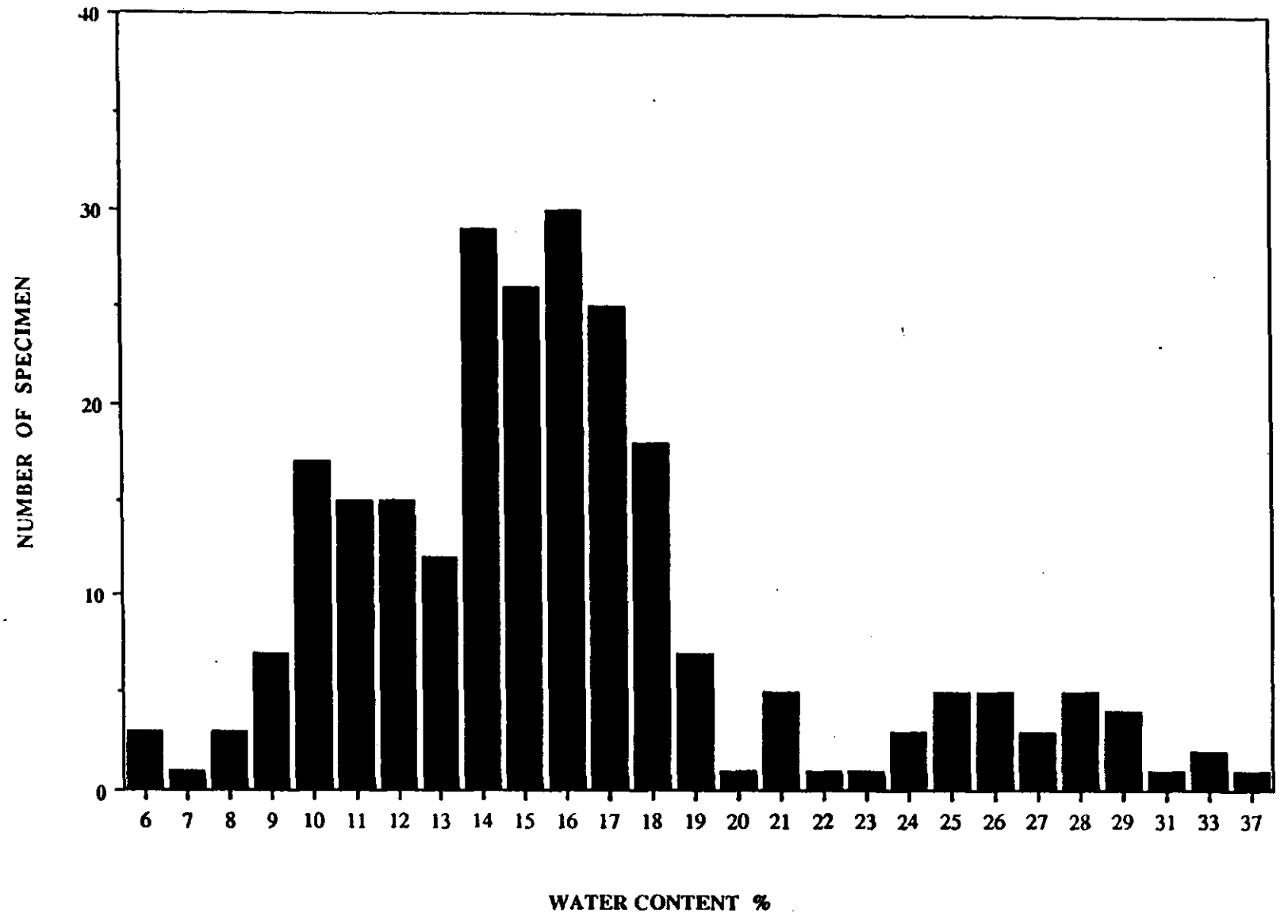


FIG. NUMBER OF SPECIMEN VS WATER CONTENT FOR MARLY CLAYSTONE

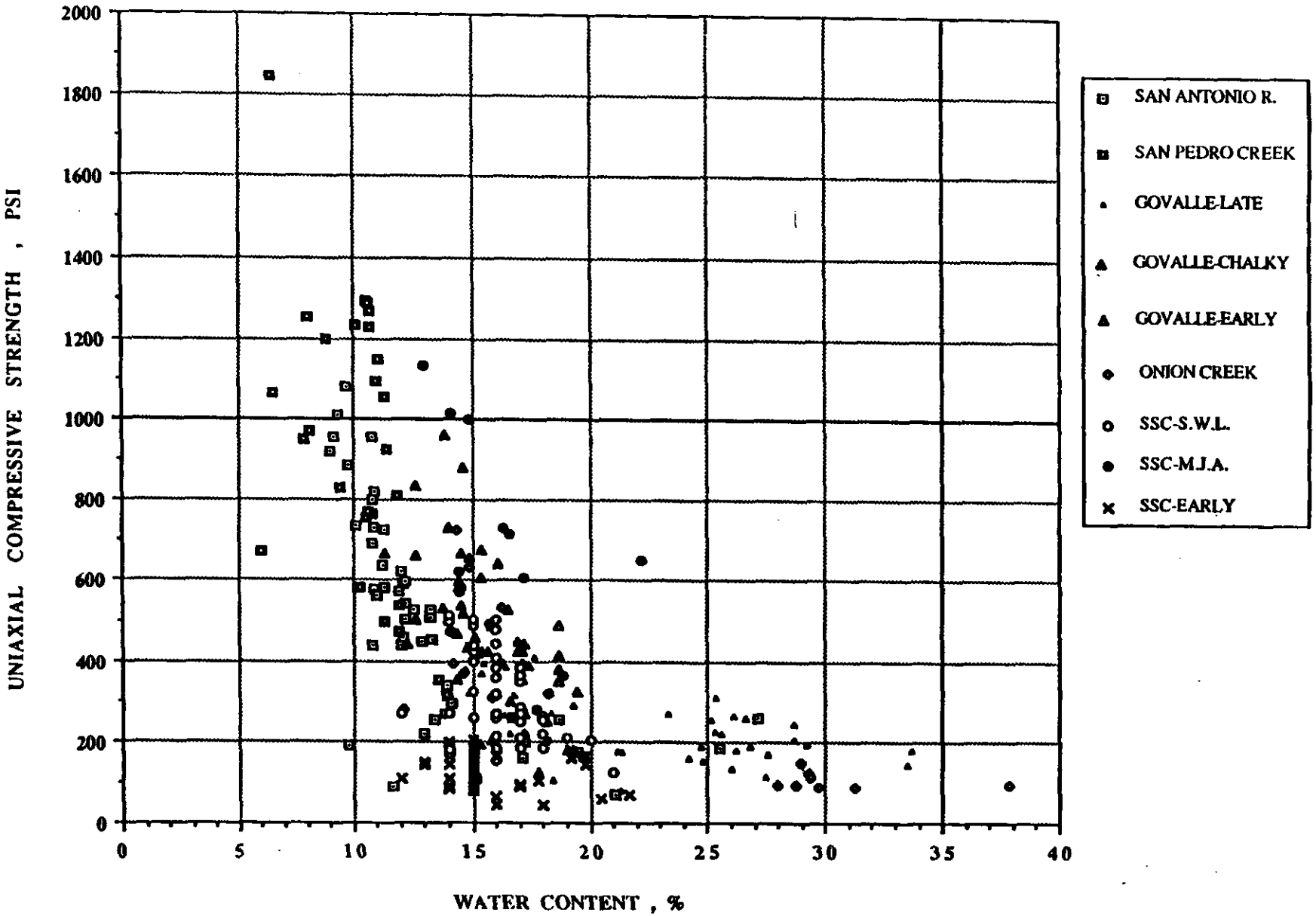


FIG. MARLY CLAYSTONE'S UNIAXIAL COMPRESSIVE STRENGTH VS WATER CONTENT

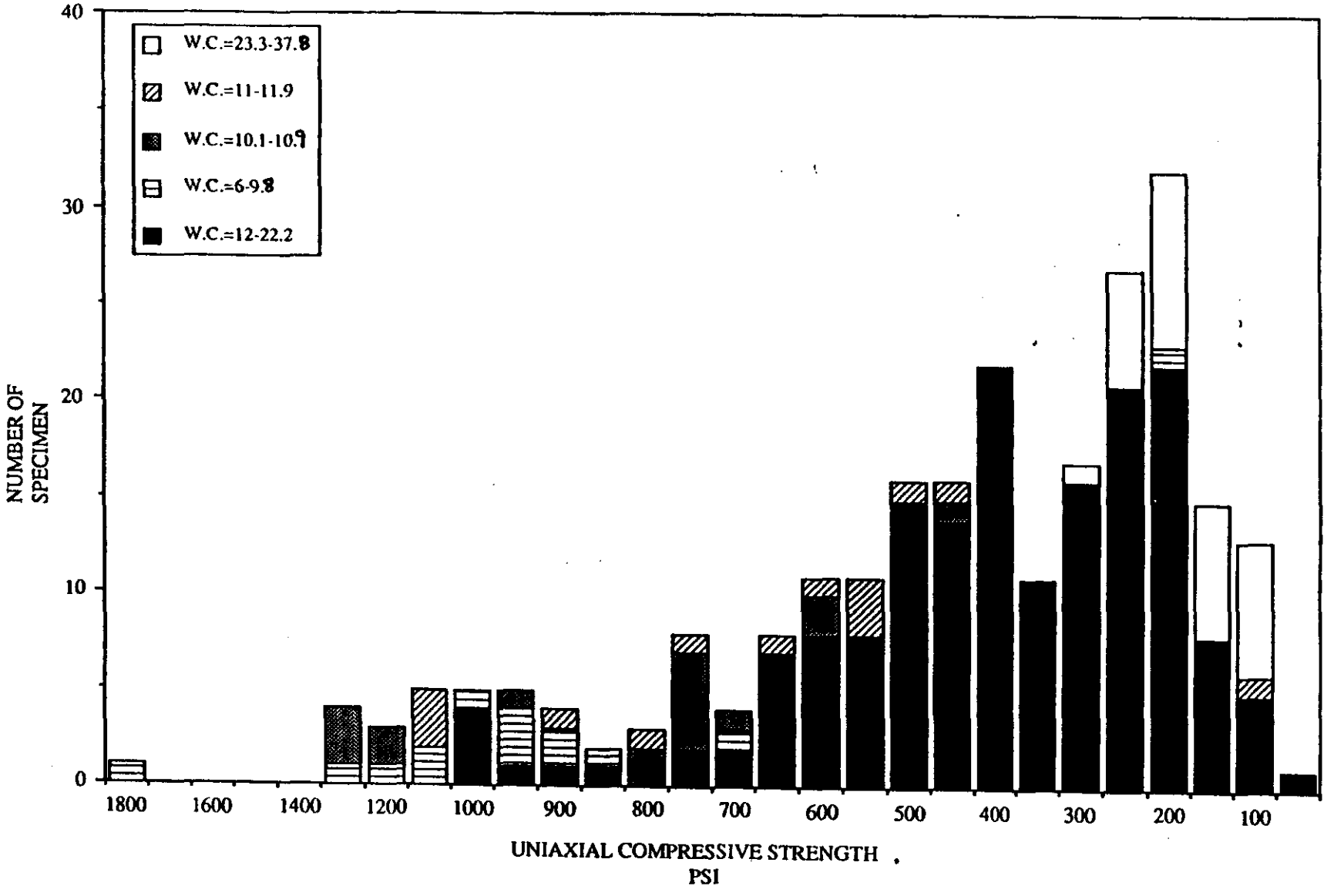
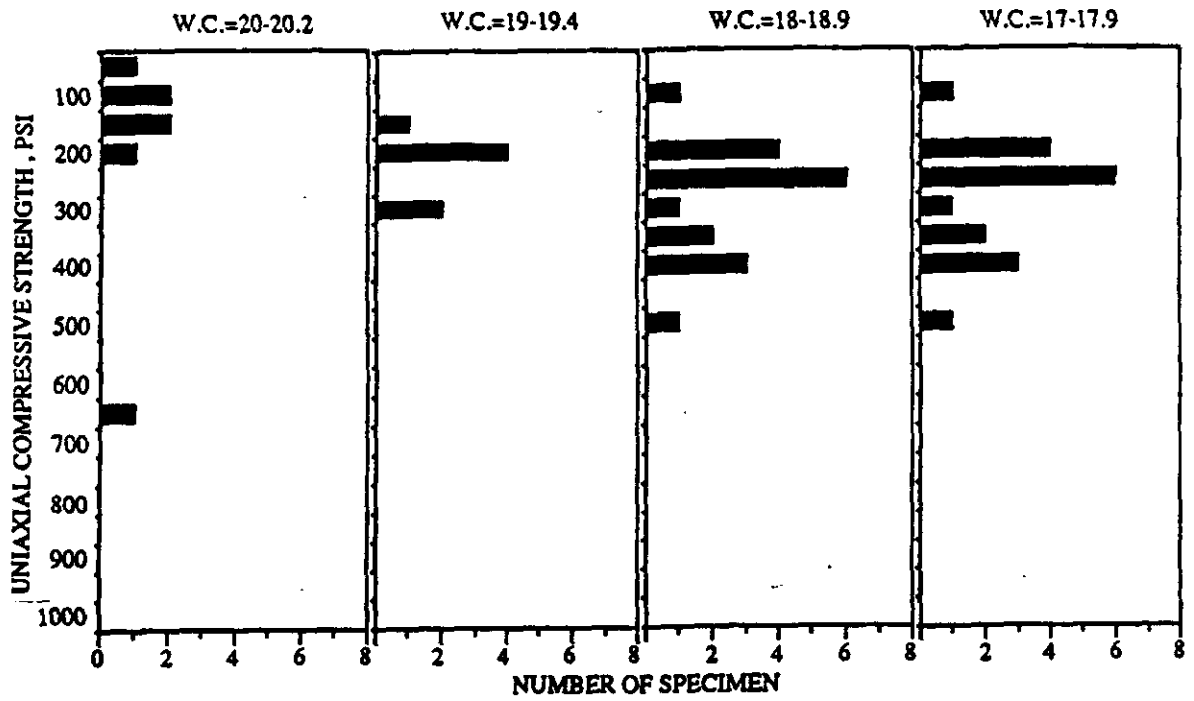


FIG. THE DISTRIBUTION OF UNIAXIAL COMPRESSIVE STRENGTH AT DIFFERENT WATER CONTENT RANGE FOR MARLY CLAYSTONE



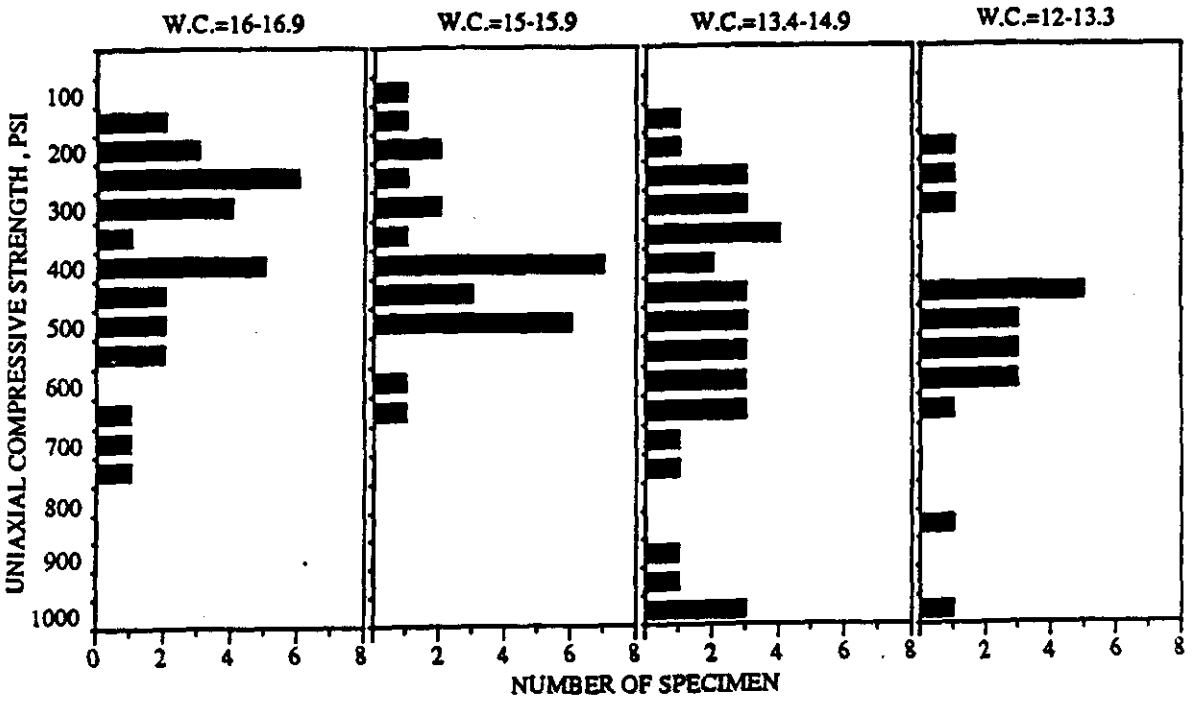
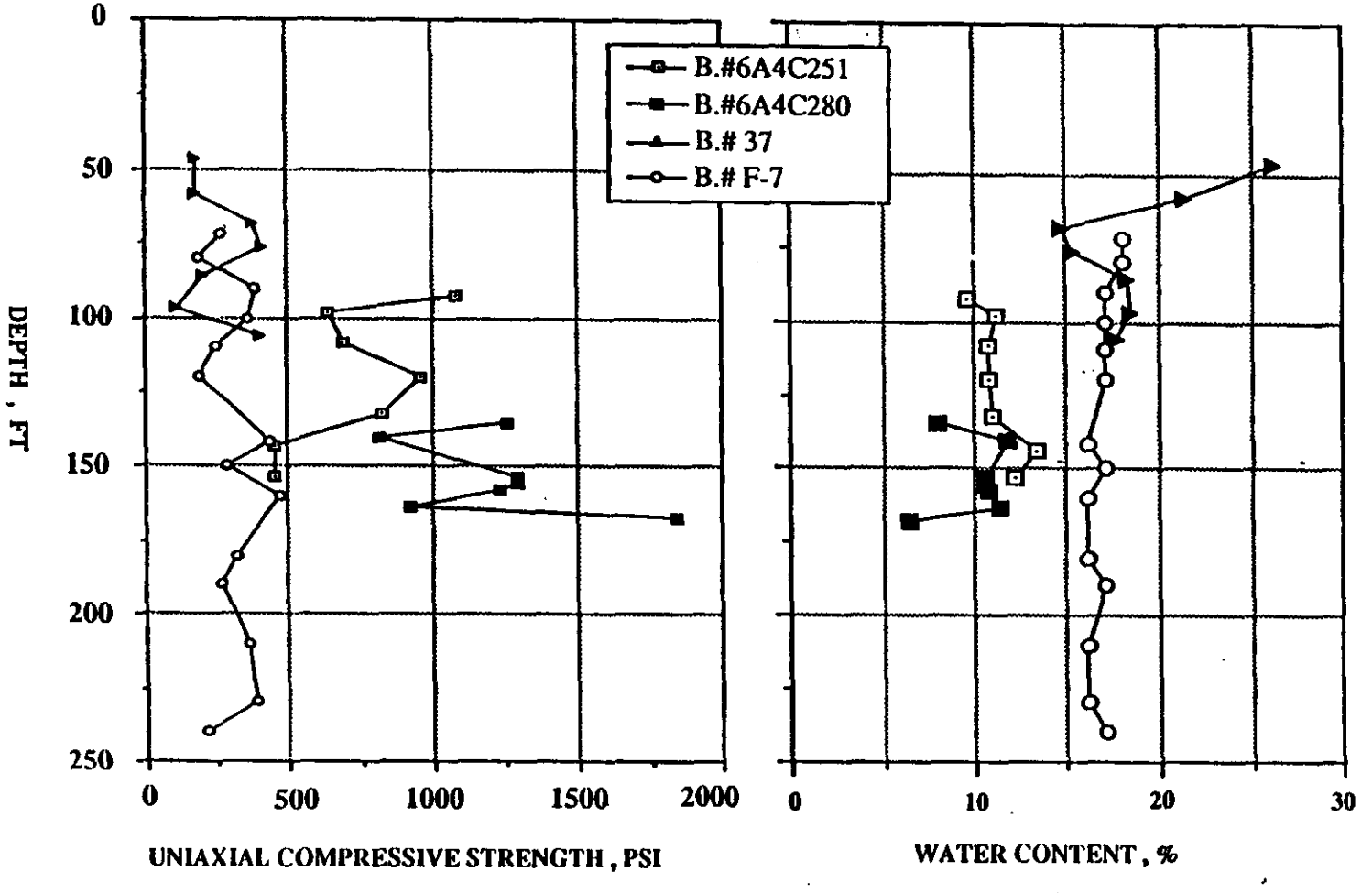
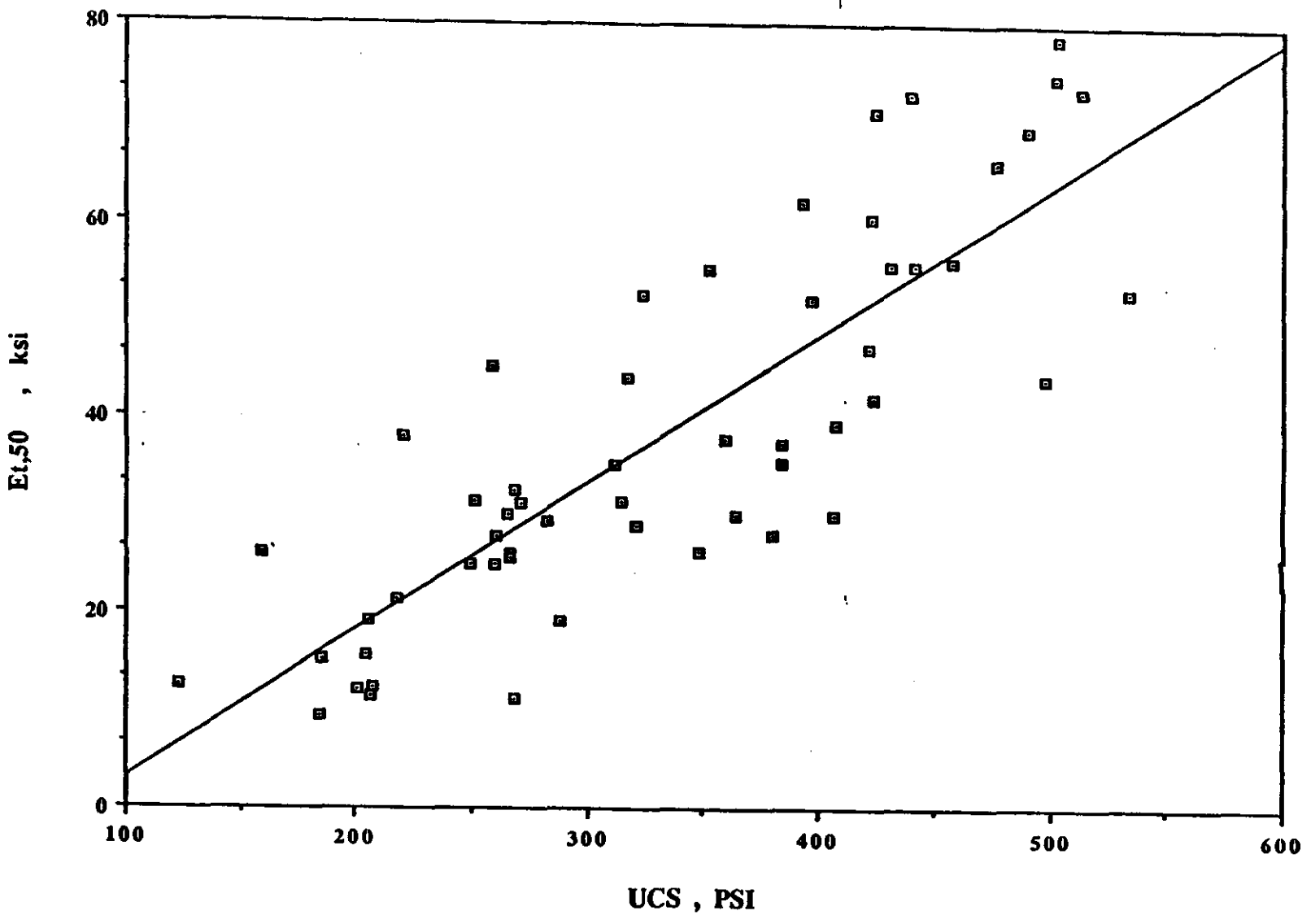


FIG. UNIAXIAL COMPRESSIVE STRENGTH,IN PSI, VS NUMBER OF SPECIMEN
AT DIFFERENCE WATER CONTENT RANGE FOR MARLY CLAYSTONE


B.#6A4C251
B.#6A4C280
B.# 37
B.# F-7
DEPTH , FT
0
50
100
150
200
250
0
500
1000
1500
2000
UNIAXIAL COMPRESSIVE STRENGTH , PSI
0
10
20
30
WATER CONTENT , %



$$\frac{E_{t,50}}{UCS} \cong 214$$

FIG. Et,50 VS UNIAXIAL COMPRESSIVE STRENGTH FOR MARLY CLAYSTONE

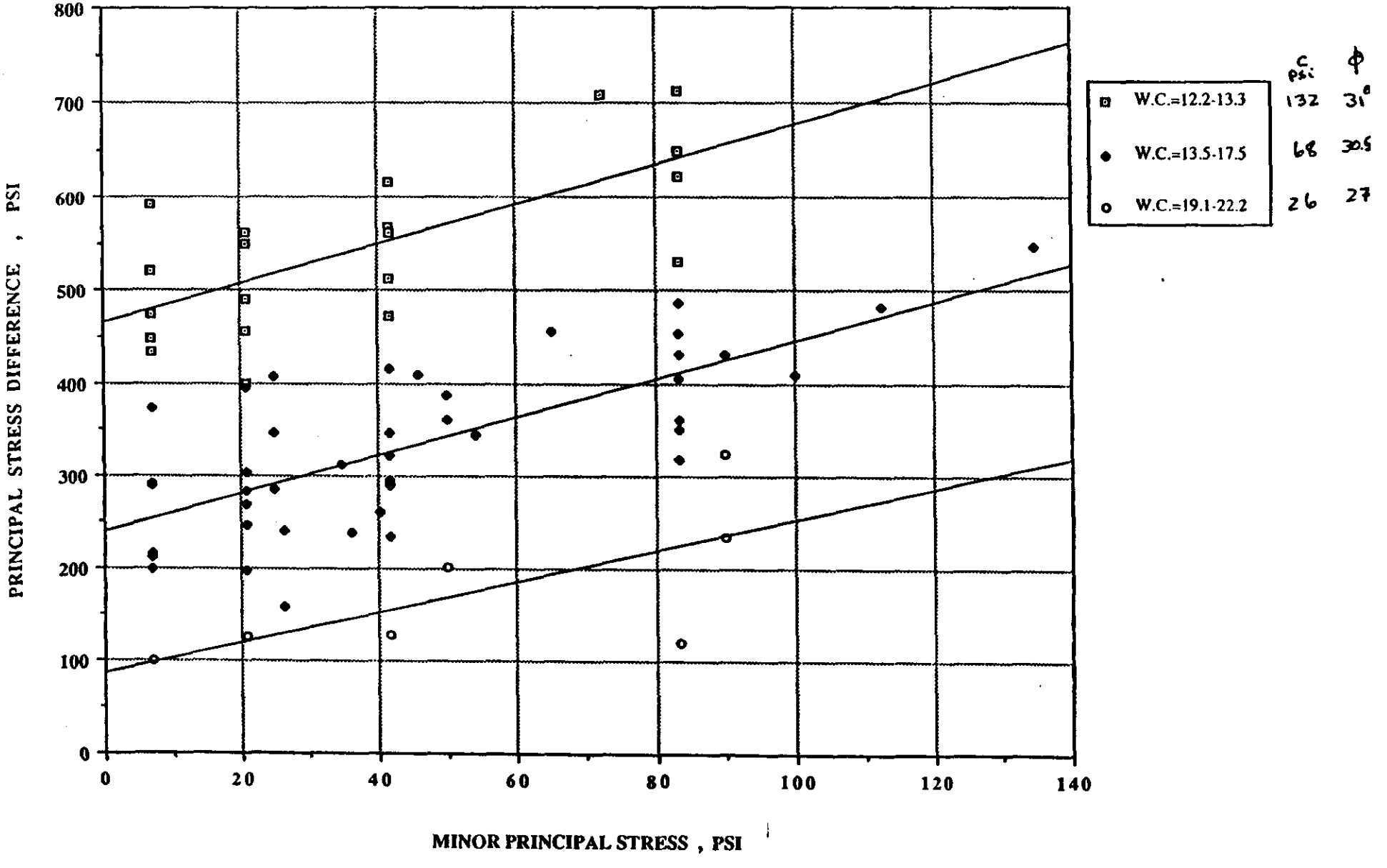


FIG. STRENGTH OF MARLY CLAYSTONE AT DIFFERENT WATER CONTENT RANGES

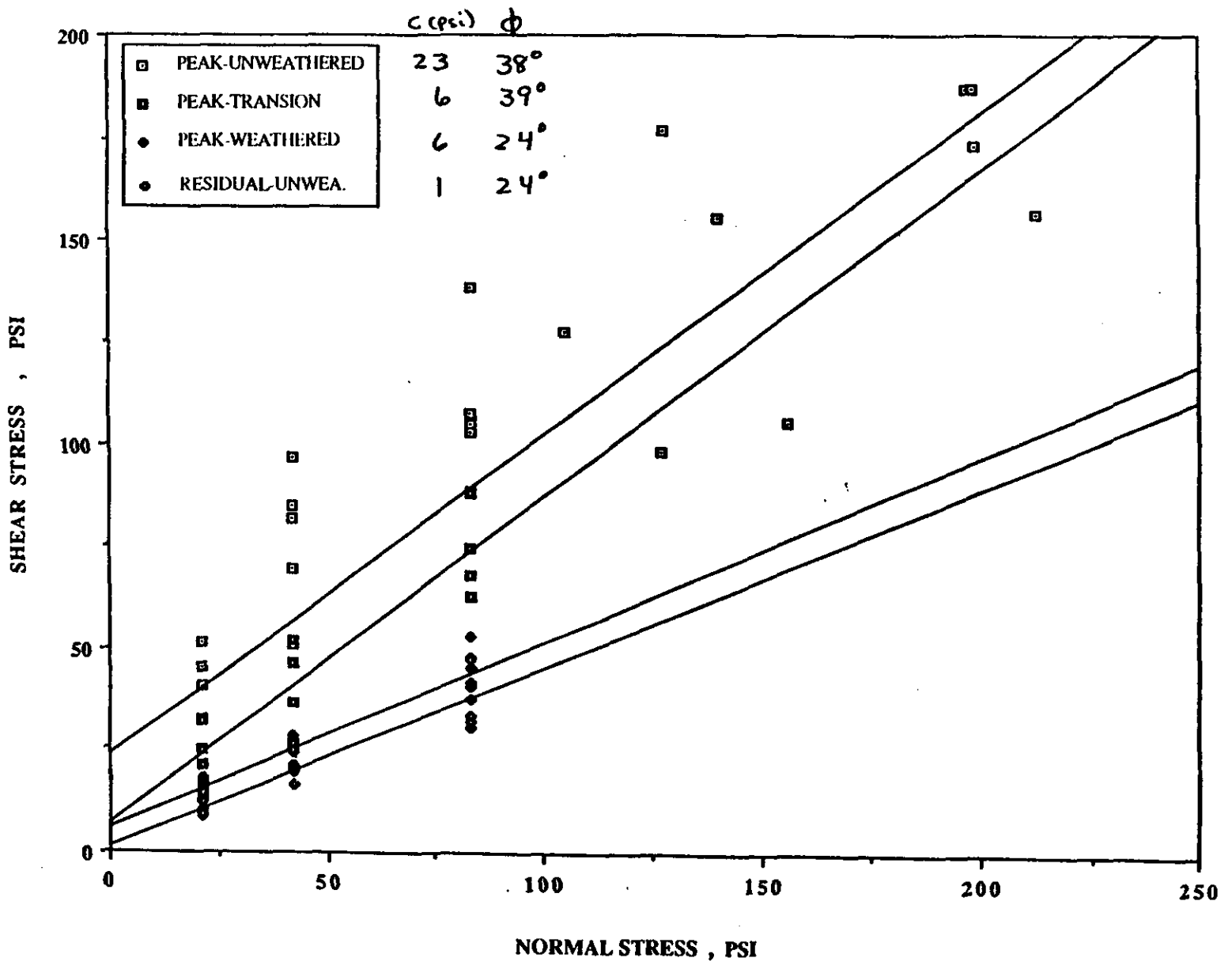


FIG. SHEAR STRESS VS NORMAL STRESS AT FAILURE PLANE, CHALK

Rock Type: TAYLOR

10'ϕ

Rock Quality: - GOOD
- POOR

	Rock Mass Classification Schemes		
	RSR	RMR	Q
Rating	94-100/38-52	69/38	22/1-3
Stand-up Time		>5 yrs/1 day	
Cohesion (psi)		50/30	
Friction Angle		40/25	45/(10)
Load on Lining (ksf)	0/0.9-1.6	0/0.8	0/None-2.0
Support Requirements	NONE/4H13 @4'-7' or B@4' + 2"S	None/	NONE/None to B@3' + 2"S

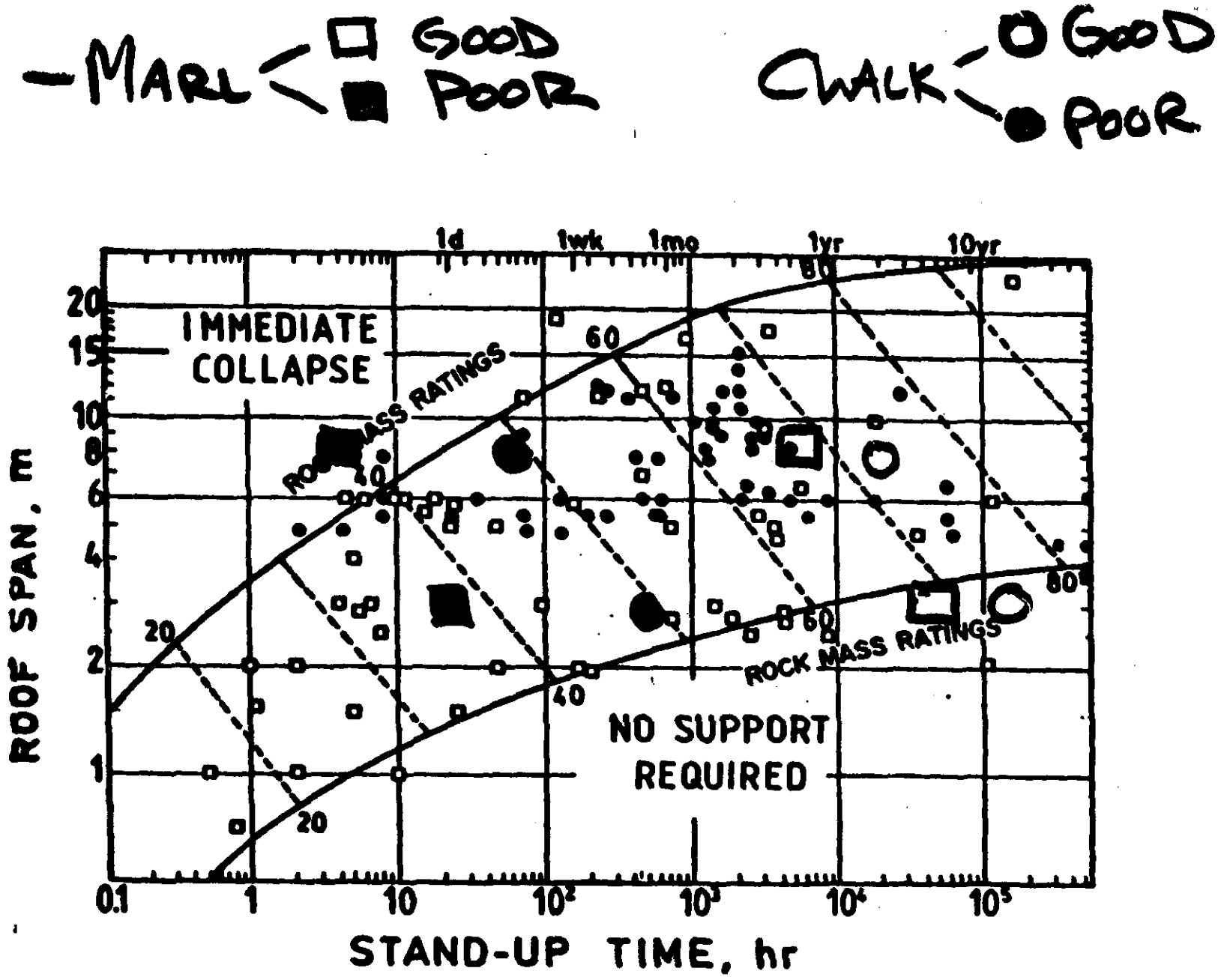
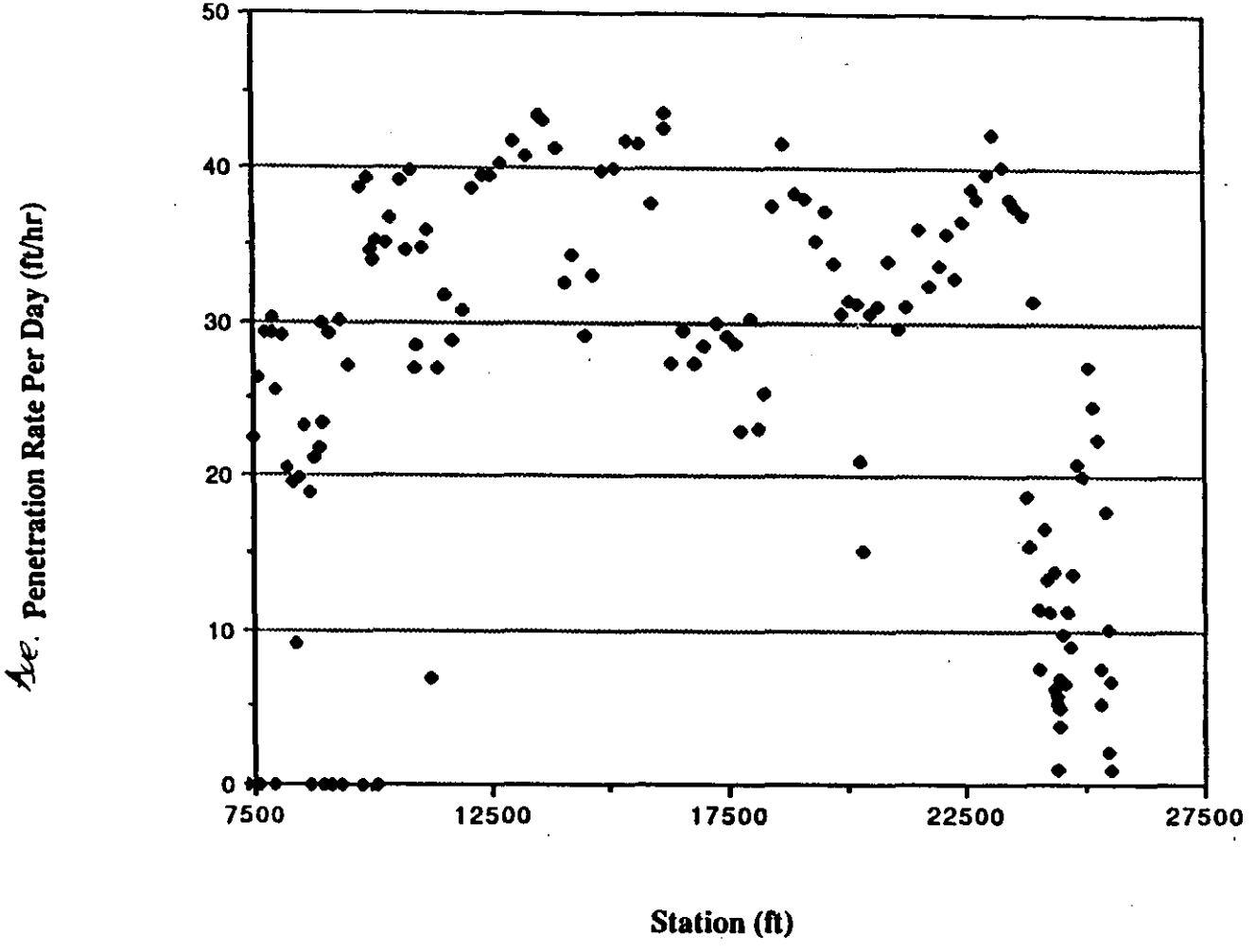
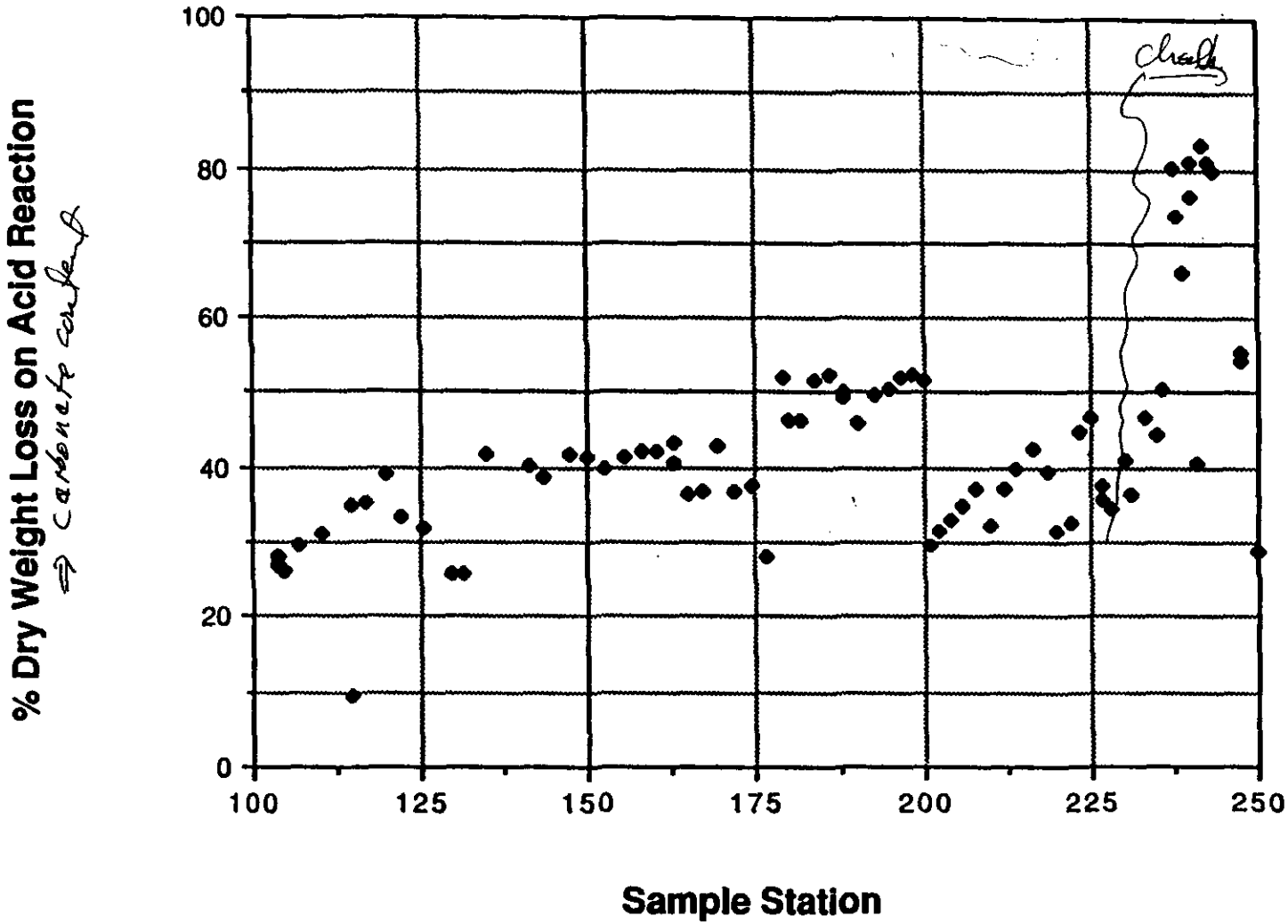


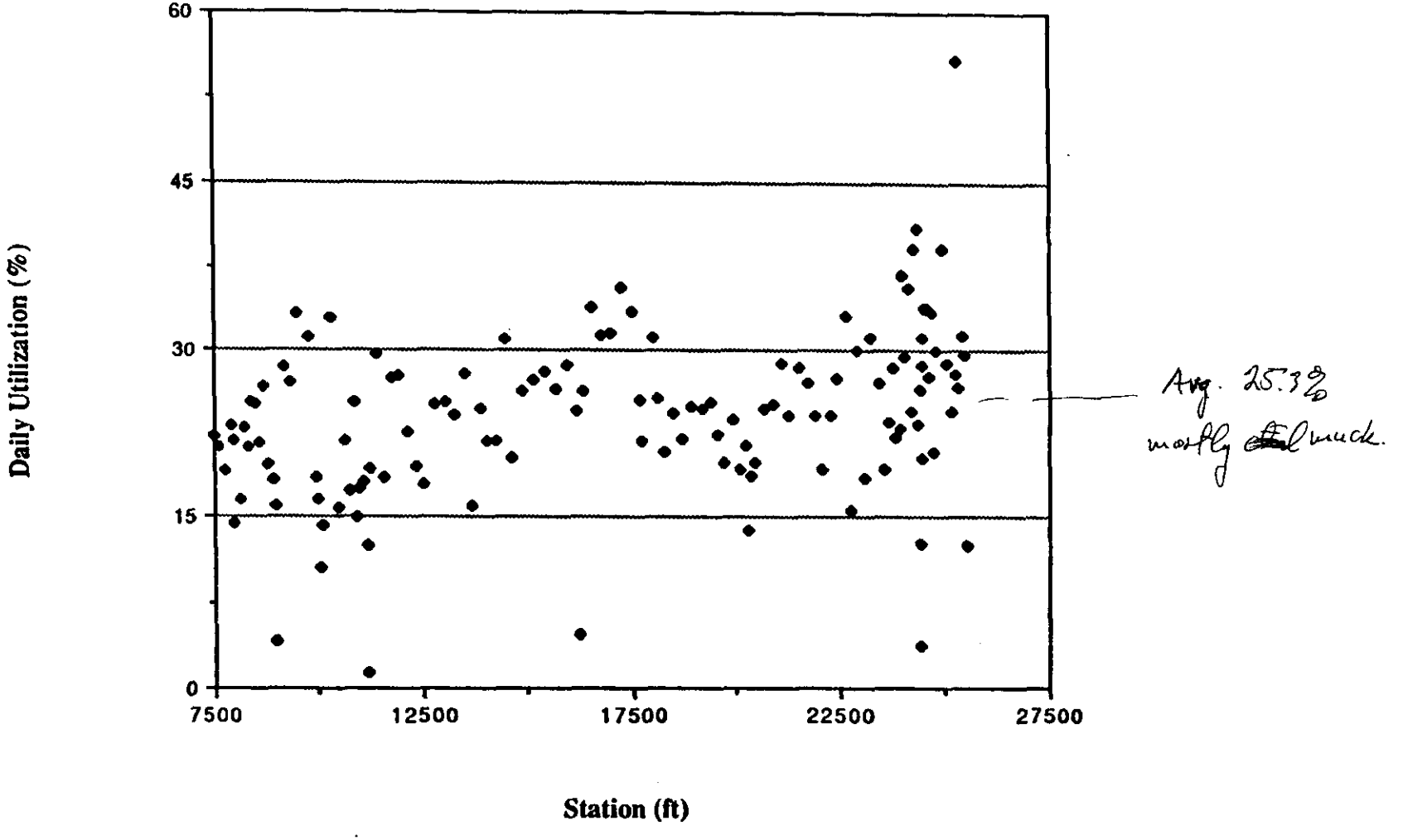
Figure 6.4. Geomechanics Classification of rock masses: output for mining and tunneling; ● = case histories of roof falls in mining; □ = tunneling roof falls; contour lines = limits of applicability.

Lovat TBM in Taylor Marl

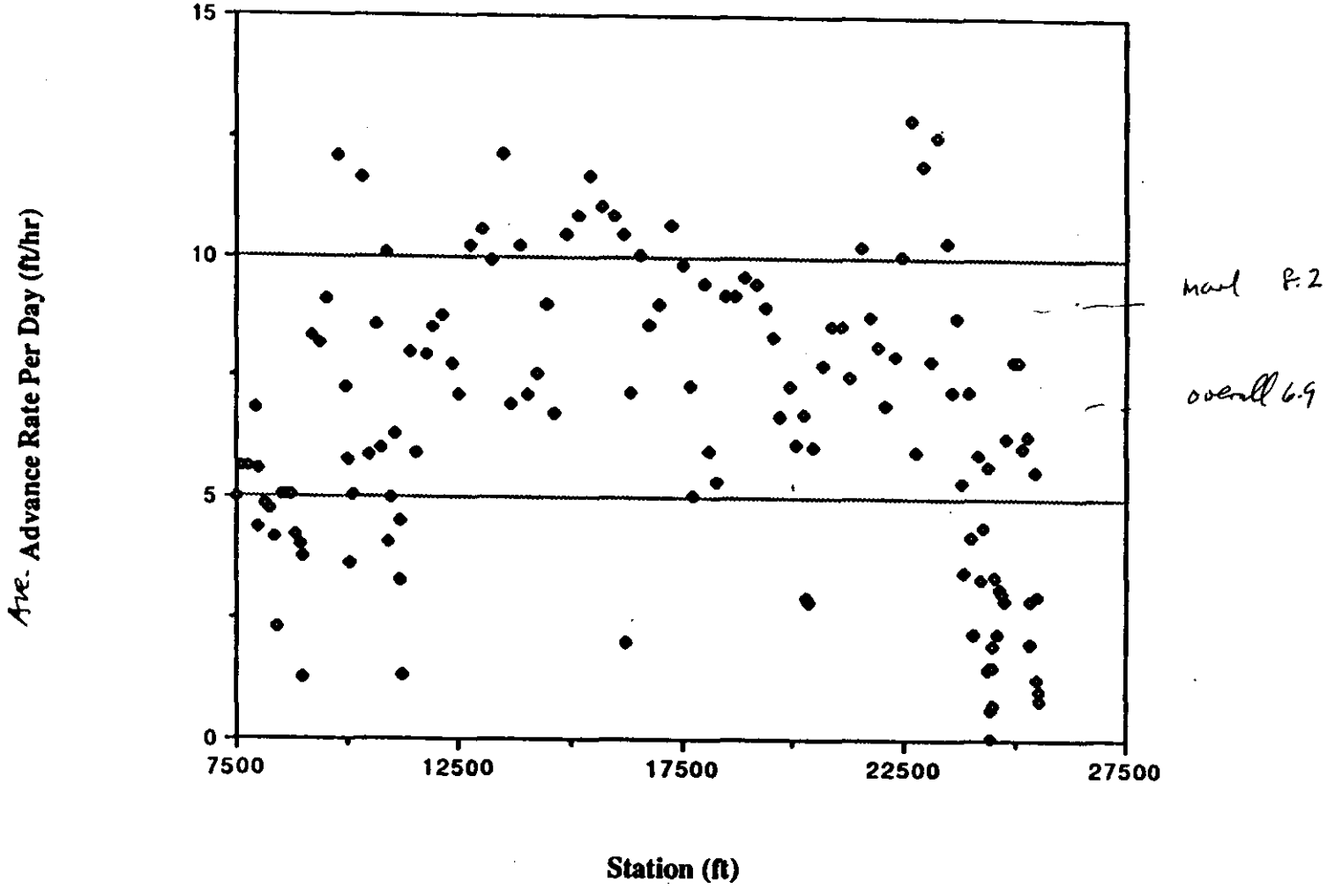


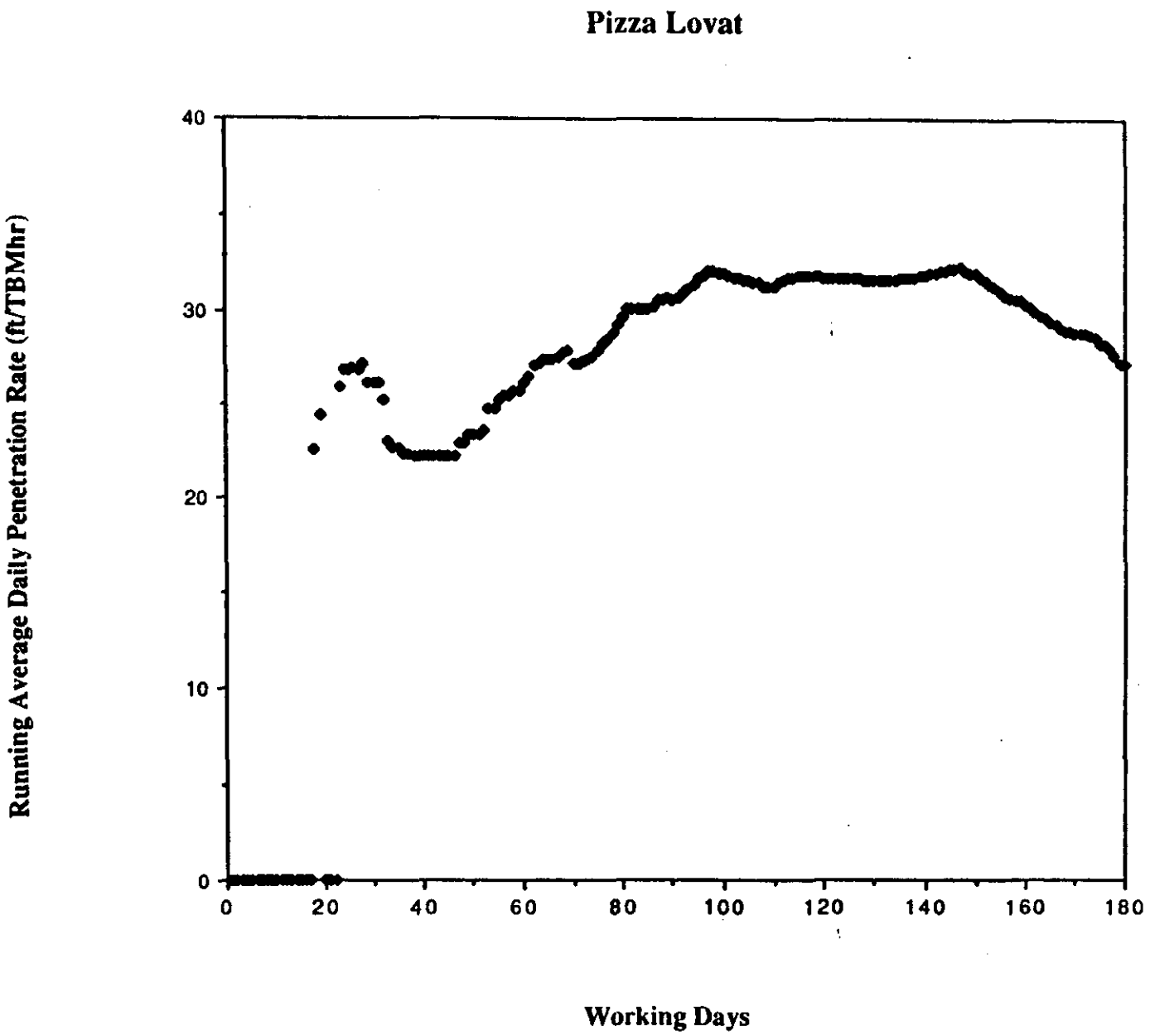

% Dry Weight Loss on Acid Reaction
⇒ carbonate content
100
80
60
40
20
0
100
125
150
175
200
225
250
Sample Station
Chalk

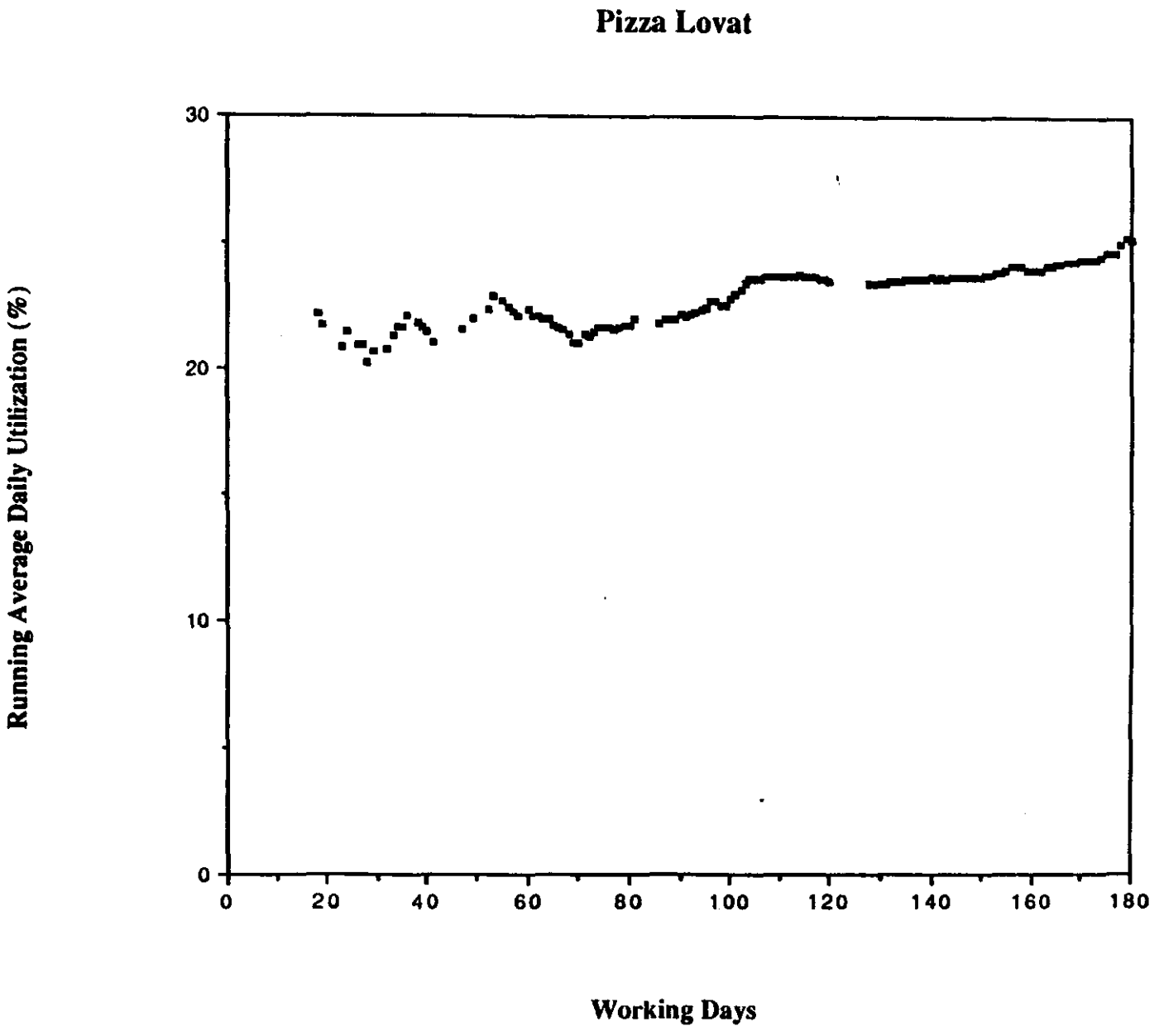
Lovat TBM in Taylor Marl

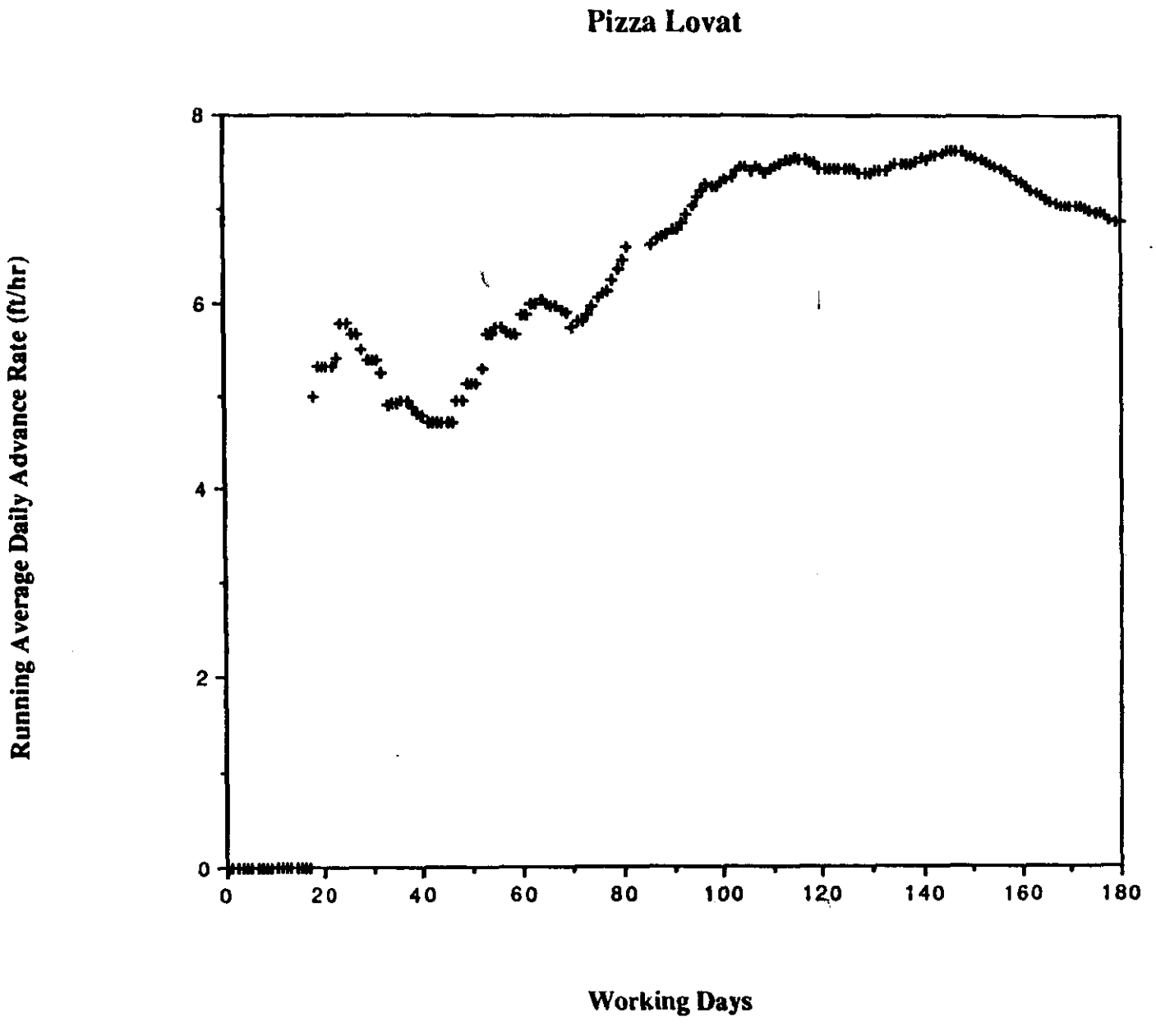


Lovat TBM in Taylor Marl

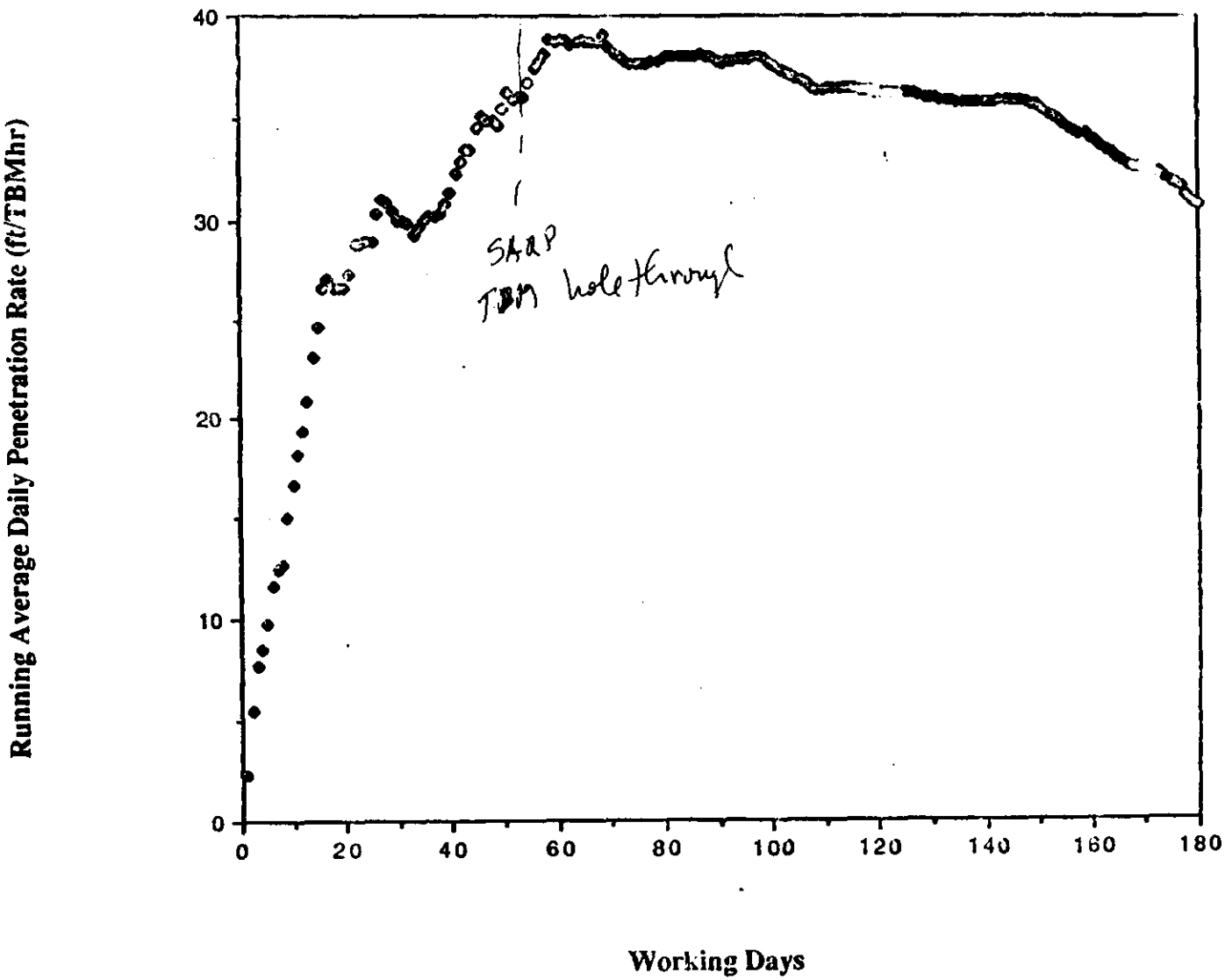



Pizza Lovat
Running Average Daily Penetration Rate (ft/TBMhr)
40
30
20
10
0
0
20
40
60
80
100
120
140
160
180
Working Days

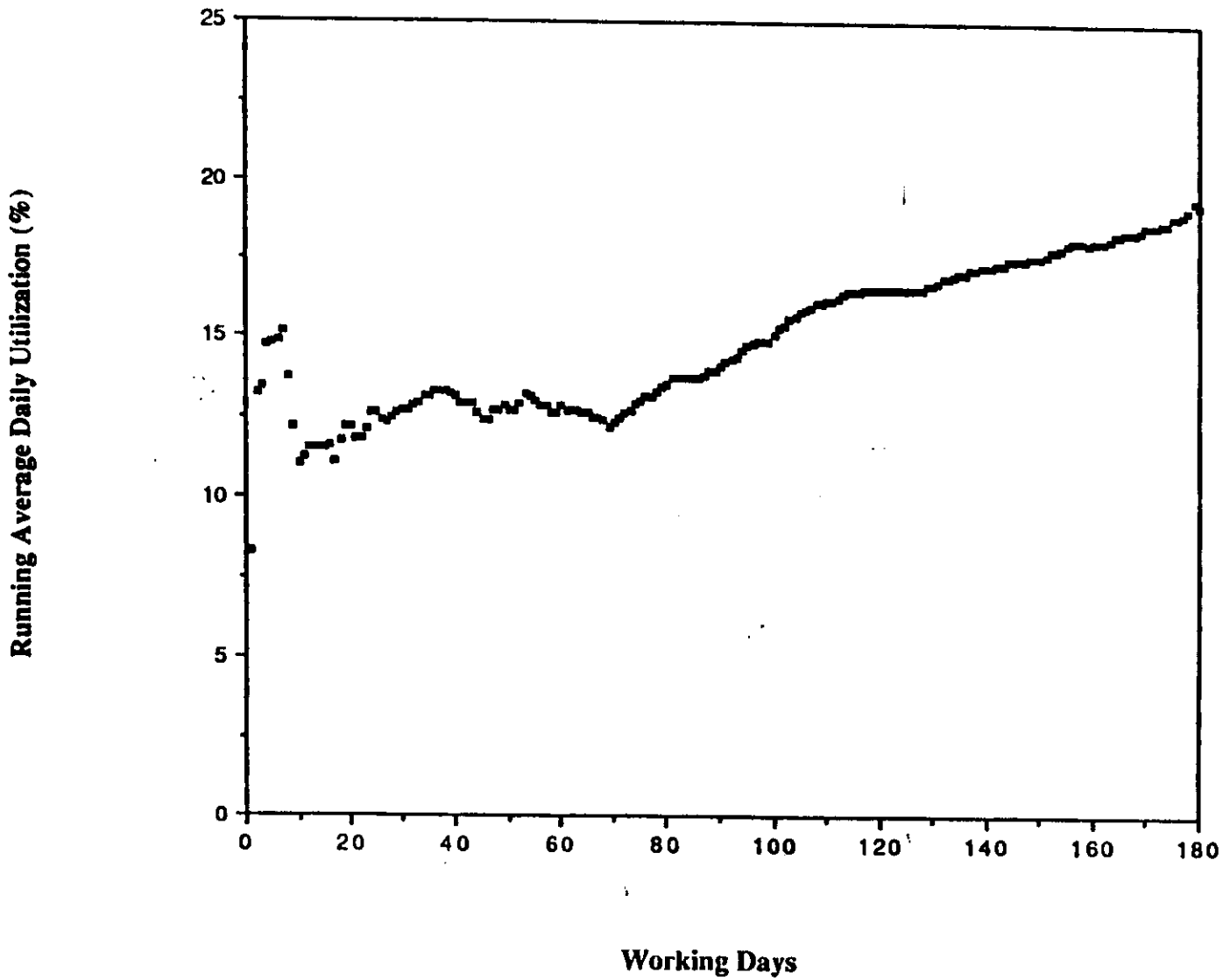

Pizza Lovat
Running Average Daily Utilization (%)
30
20
10
0
0
20
40
60
80
100
120
140
160
180
Working Days


Pizza Lovat
Running Average Daily Advance Rate (ft/hr)
Working Days
0
2
4
6
8
0
20
40
60
80
100
120
140
160
180

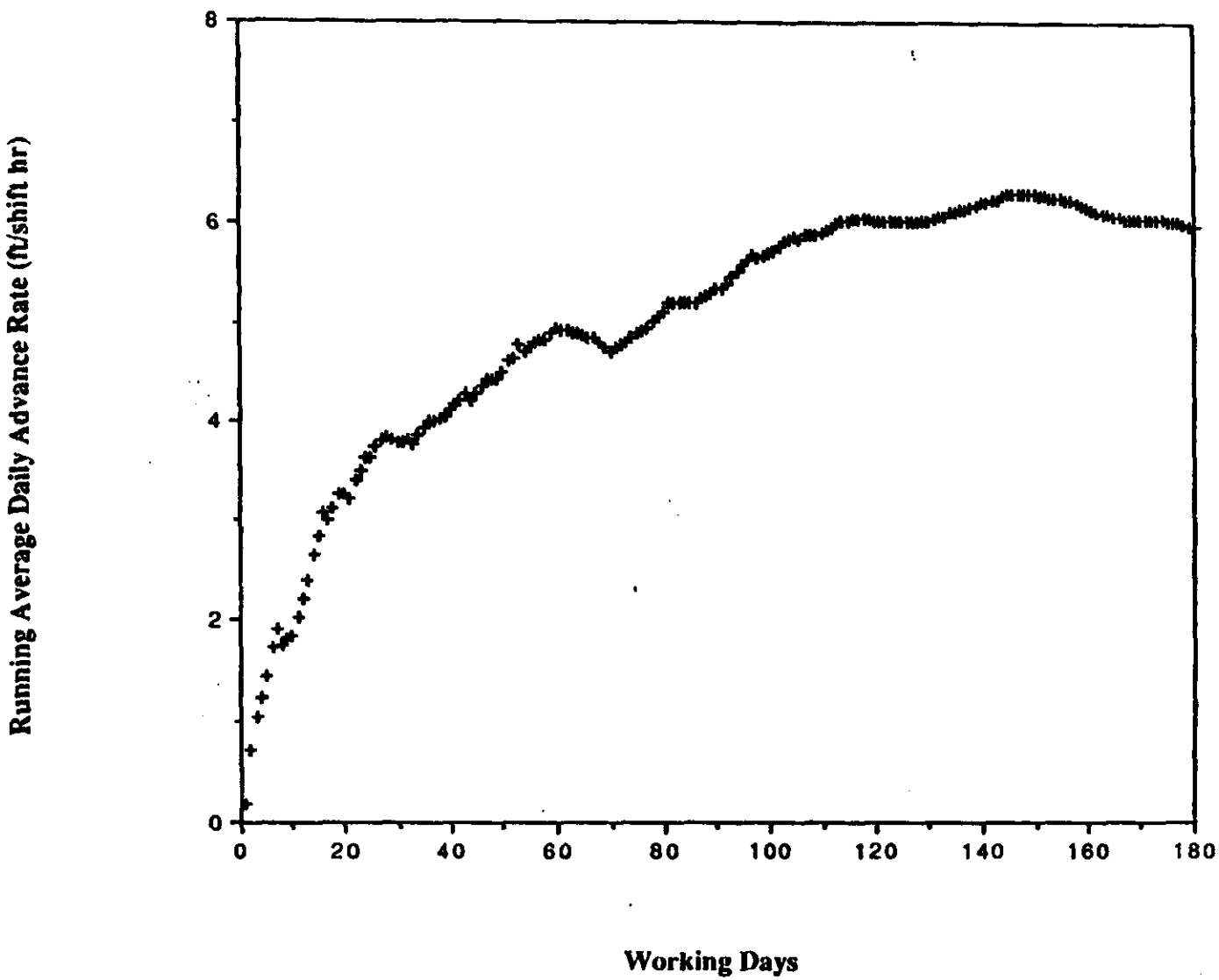
Combined Lovats in Taylor Marl



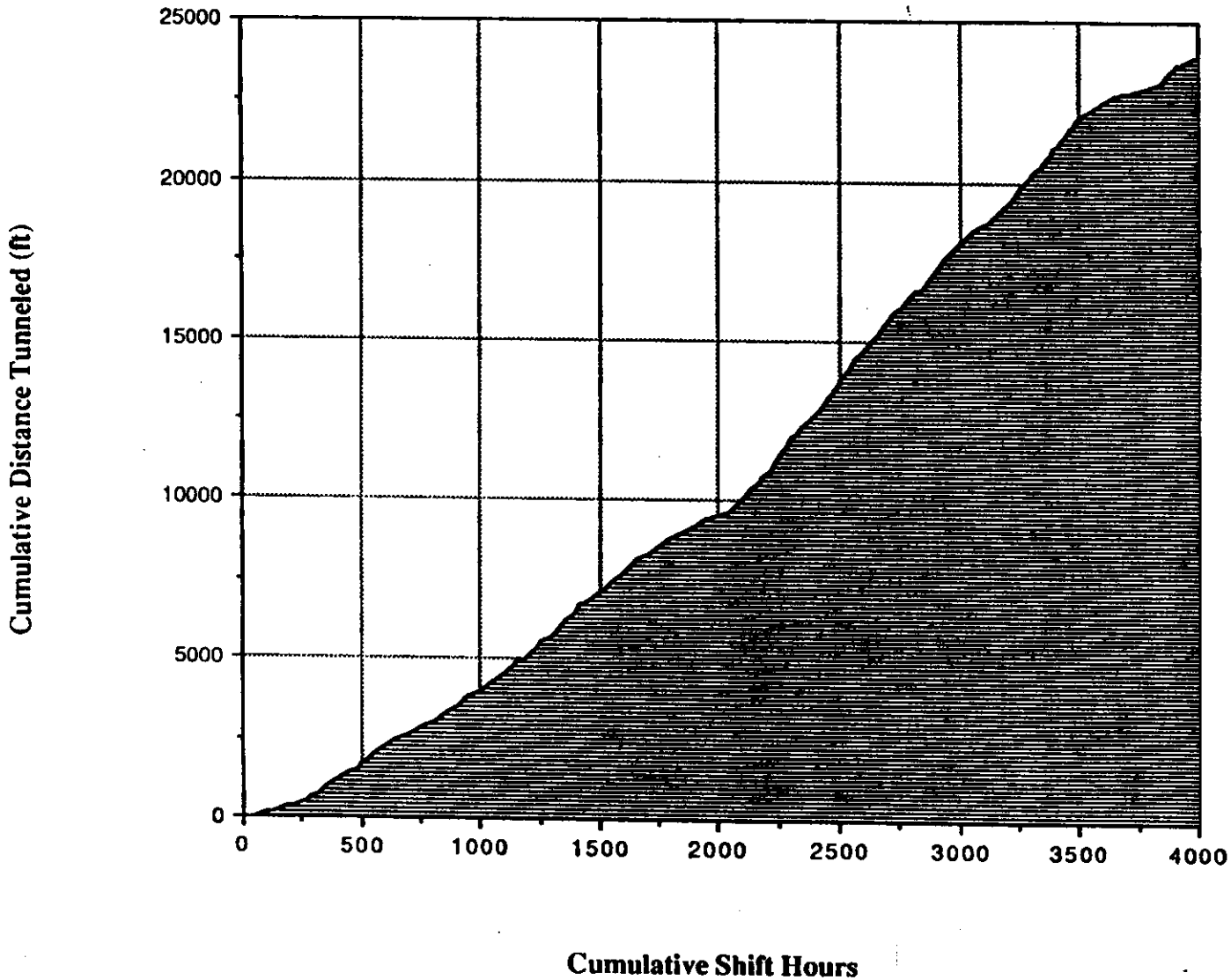
Combined Lovats in Taylor Marl



Combined Lovats in Taylor Marl



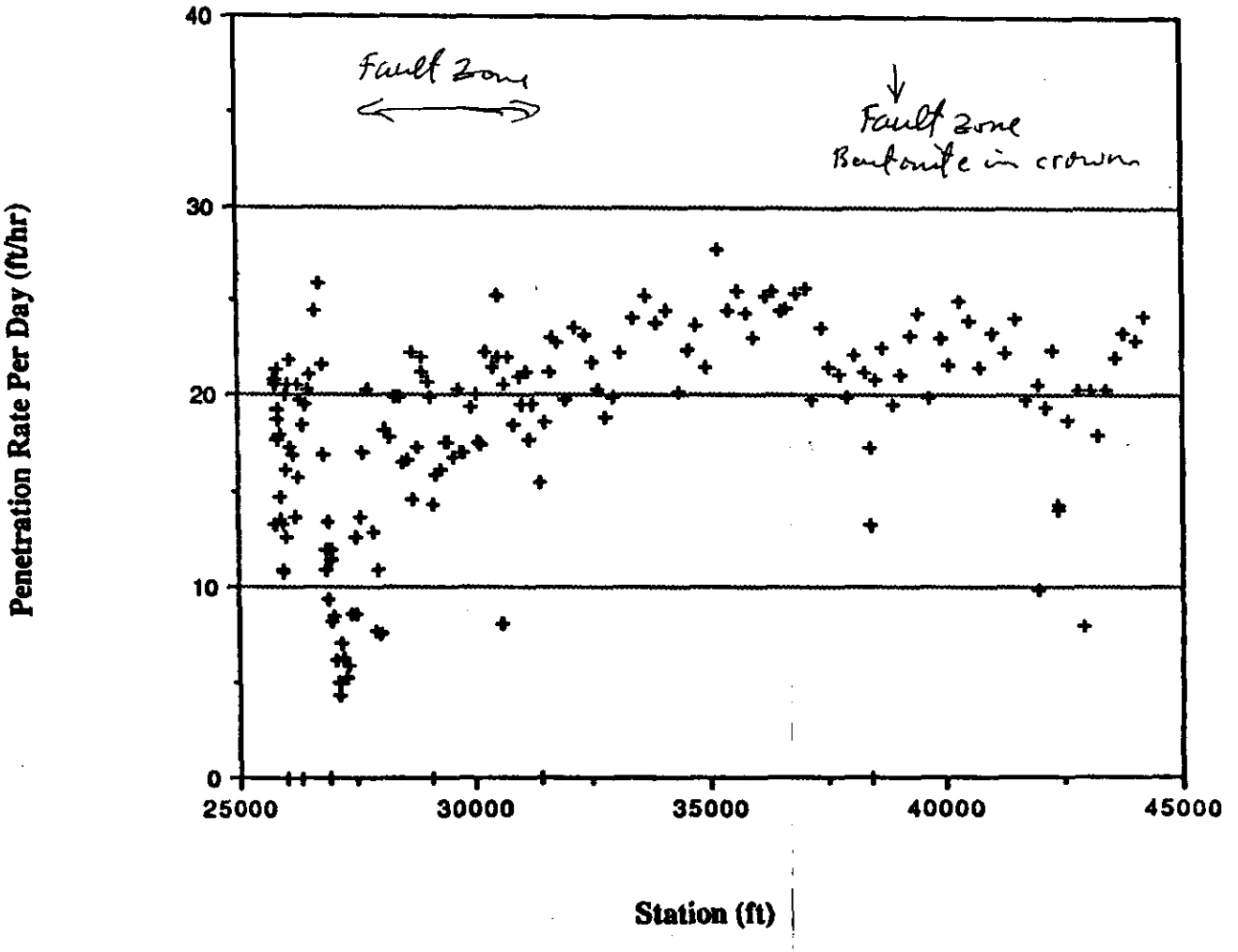
Combined Lovats in Taylor Marl

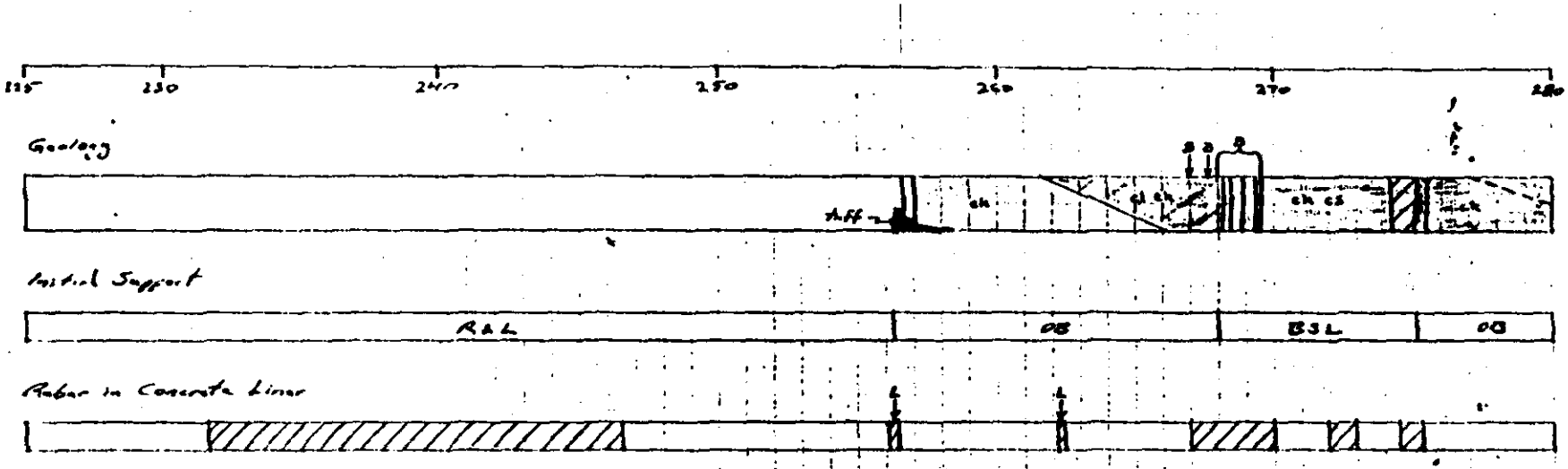


LOVAT TBM PERFORMANCE

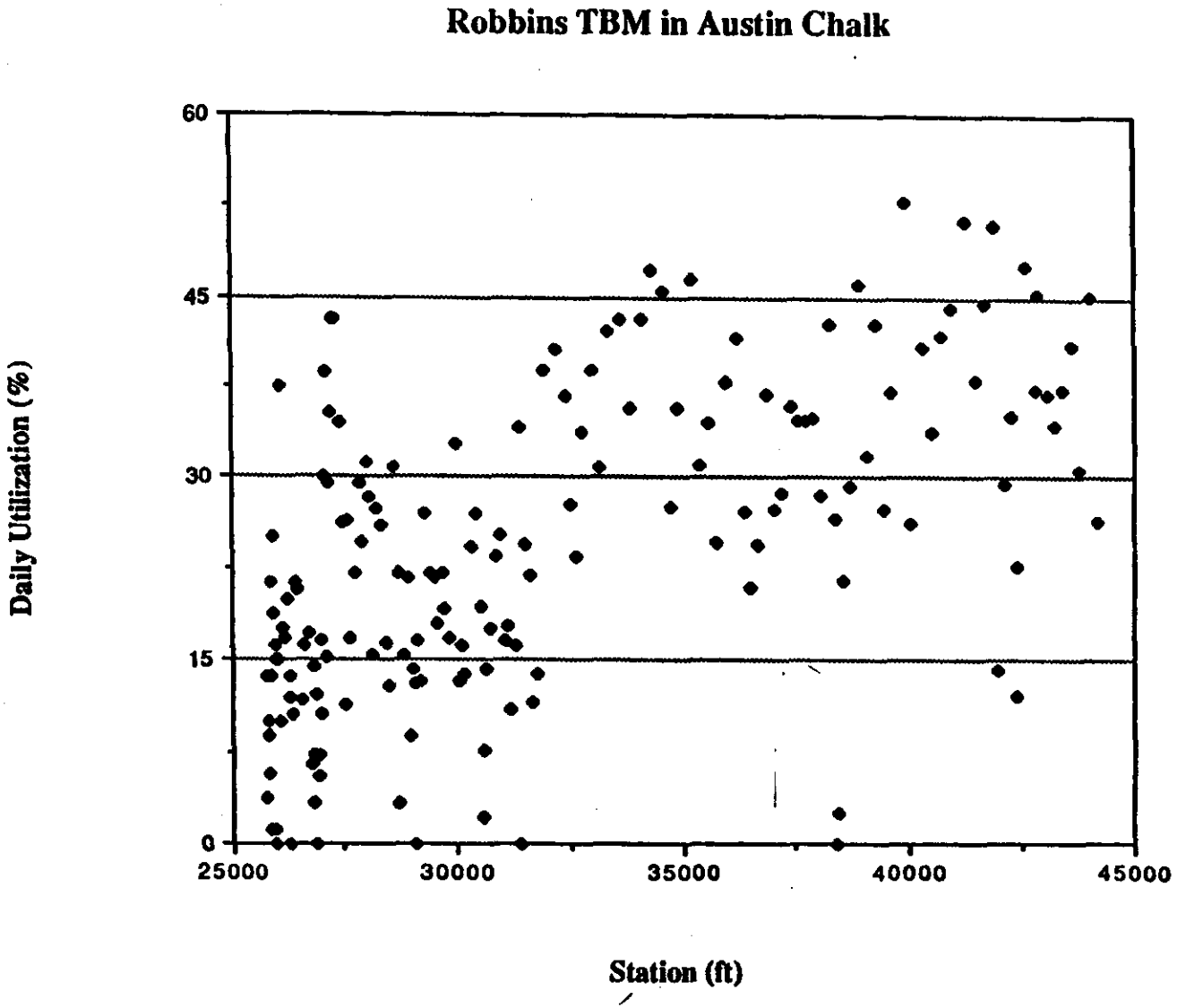
	U%	PR ft/TBM HR	AR ft/Shift HR
MARL	23.7	32.3	7.6
CHALK	31.9	11.4	3.6
WHOLE JOB	25.3	27.2	6.9

Robbins TBM in Austin Chalk

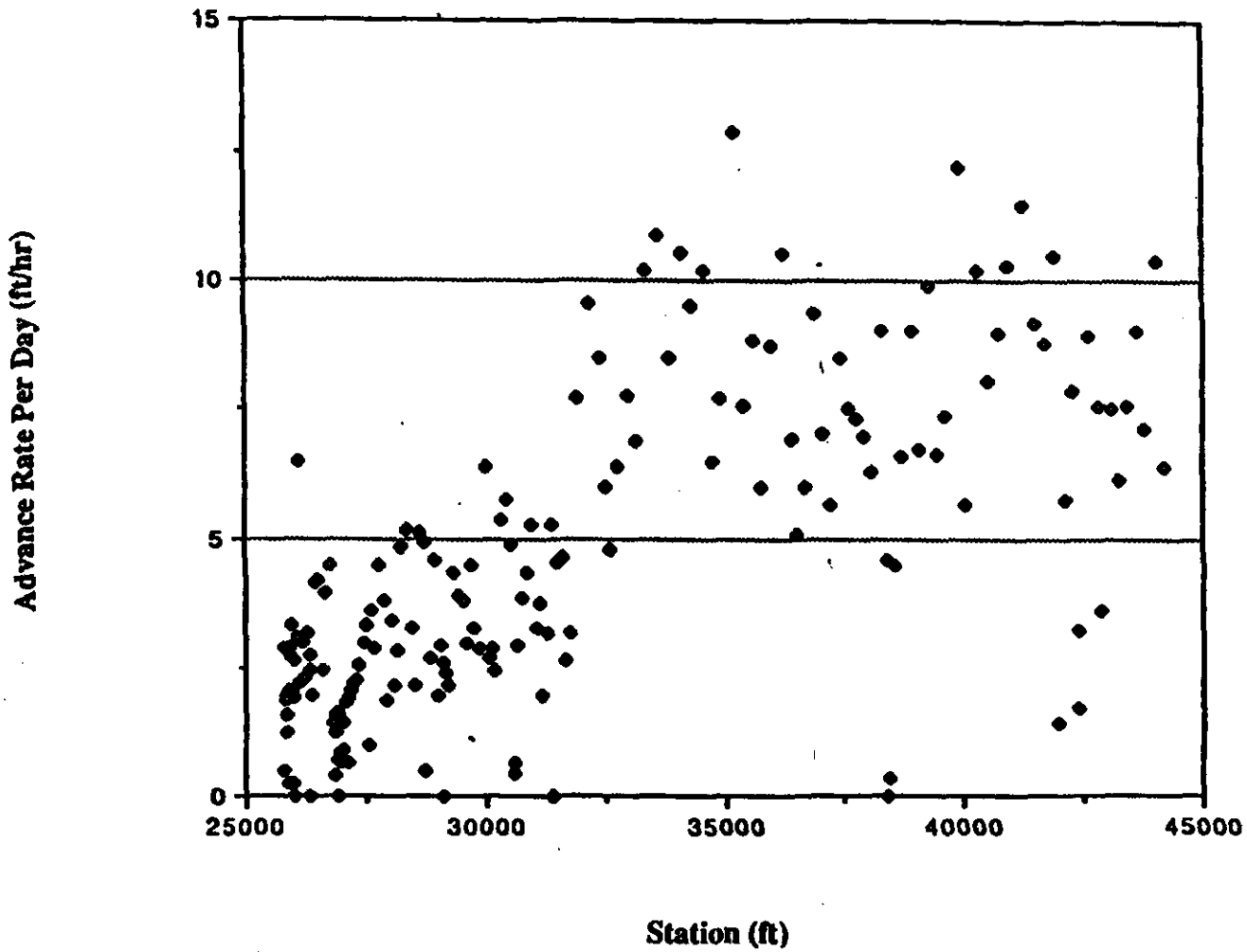


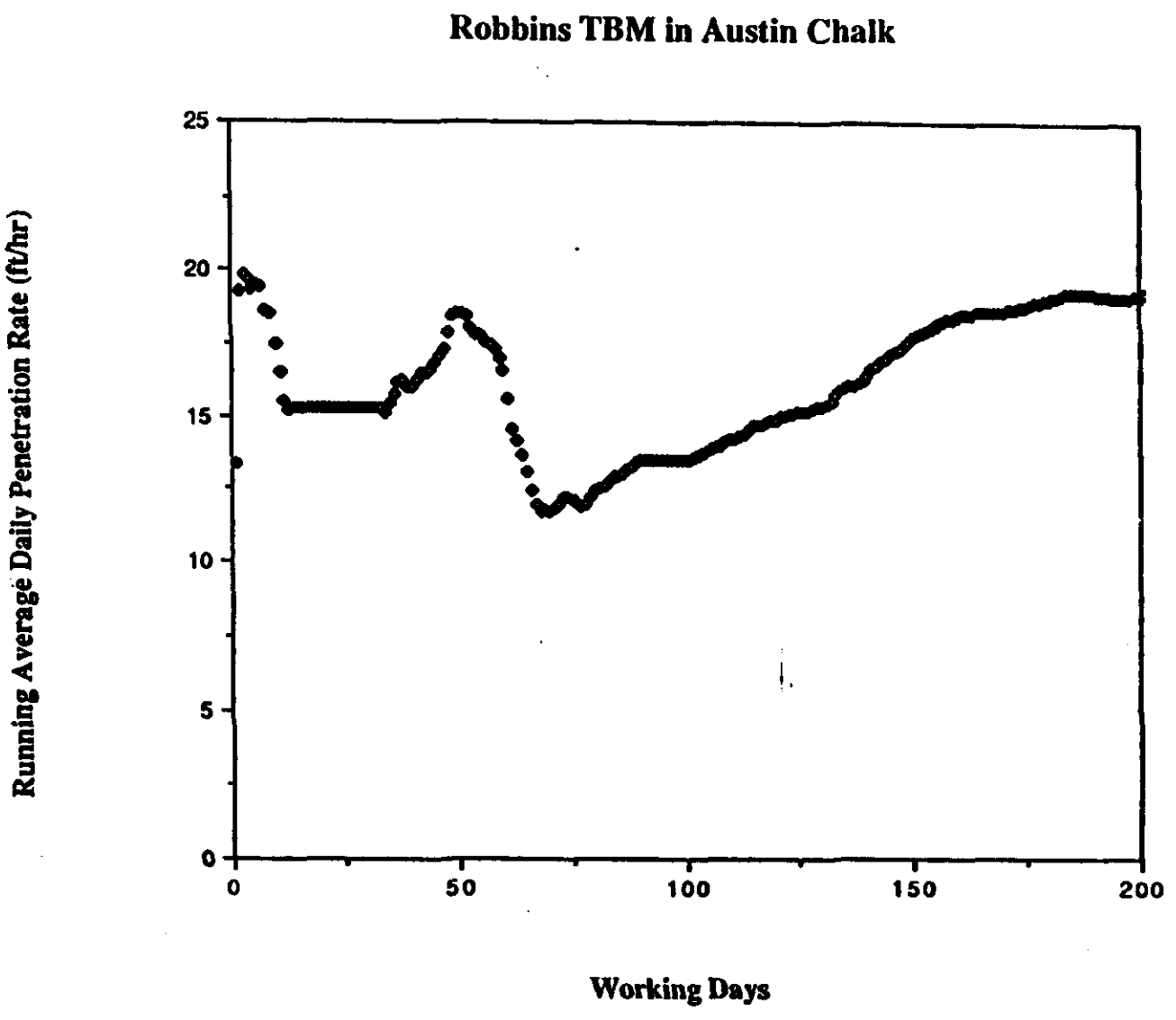


Geology		Initial Support		Rebar	
ck	chalk	R&L	ribs and lagging	L	lateral tunnel intersection
cl ck	clayey chalk	BSL	rock bolts, straps (channels), plywood lagging		
cs	claystone	OB	occasional rock bolts		
ck cs	chalky claystone	OBS	occasional rock bolts and straps		
B	block fall				
/	fault				
▨	fault zone				
—	contact between units				
b	bed or layer (b indicates bentonite)				
tuff	volcanic tuff				

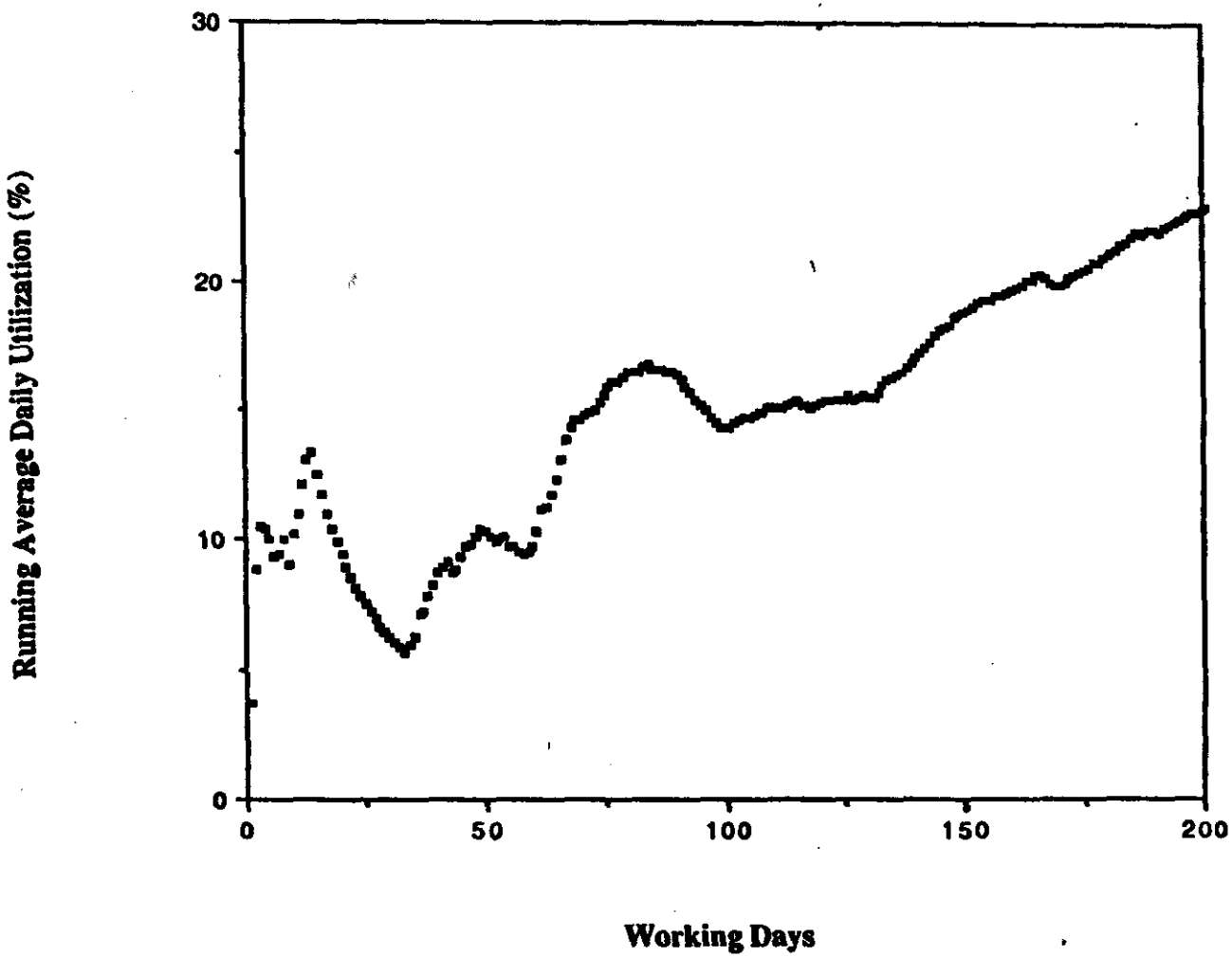

Robbins TBM in Austin Chalk
Daily Utilization (%)
60
45
30
15
0
25000
30000
35000
40000
45000
Station (ft)

Robbins TBM in Austin Chalk

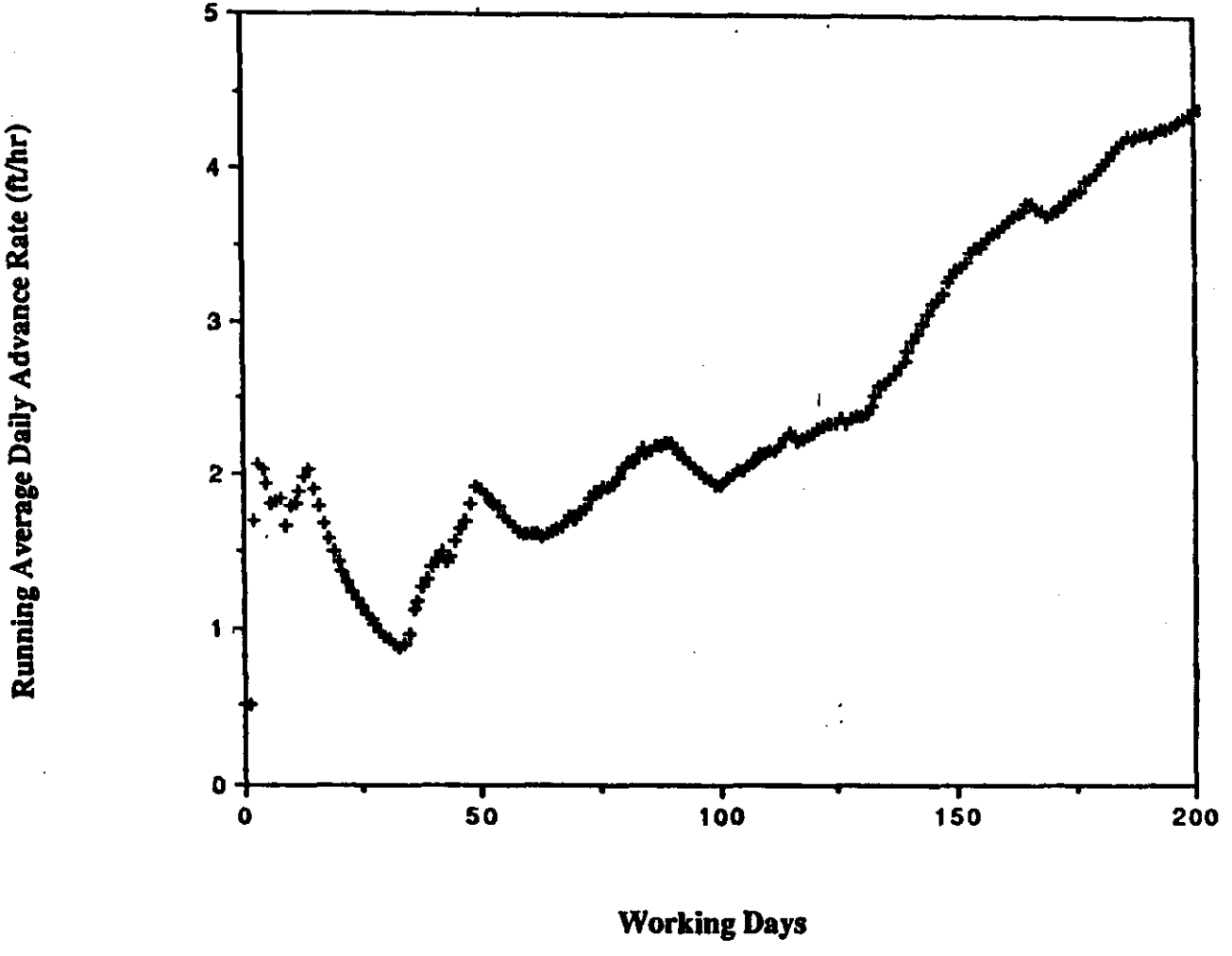


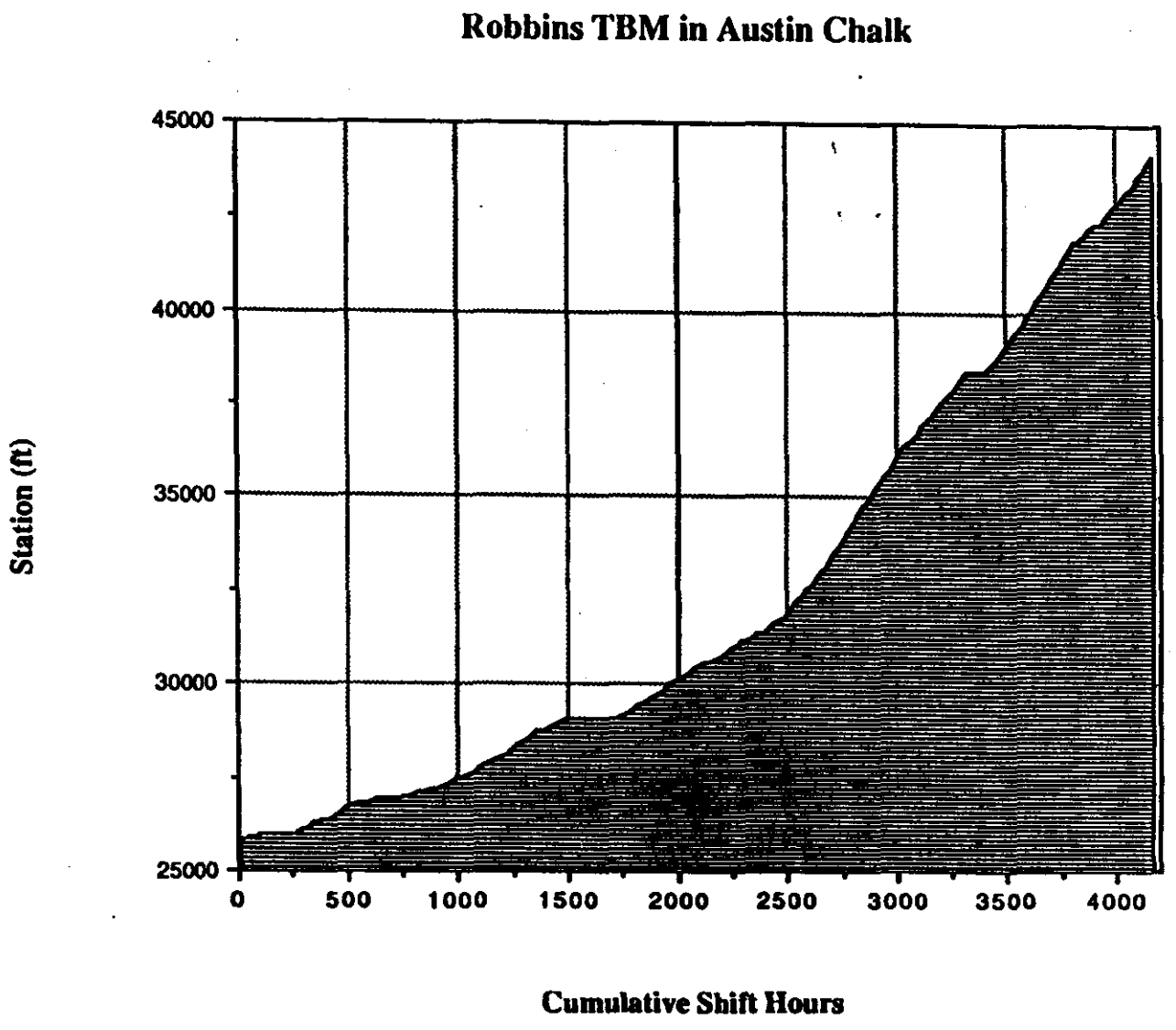

Robbins TBM in Austin Chalk
Running Average Daily Penetration Rate (ft/hr)
25
20
15
10
5
0
0
50
100
150
200
Working Days

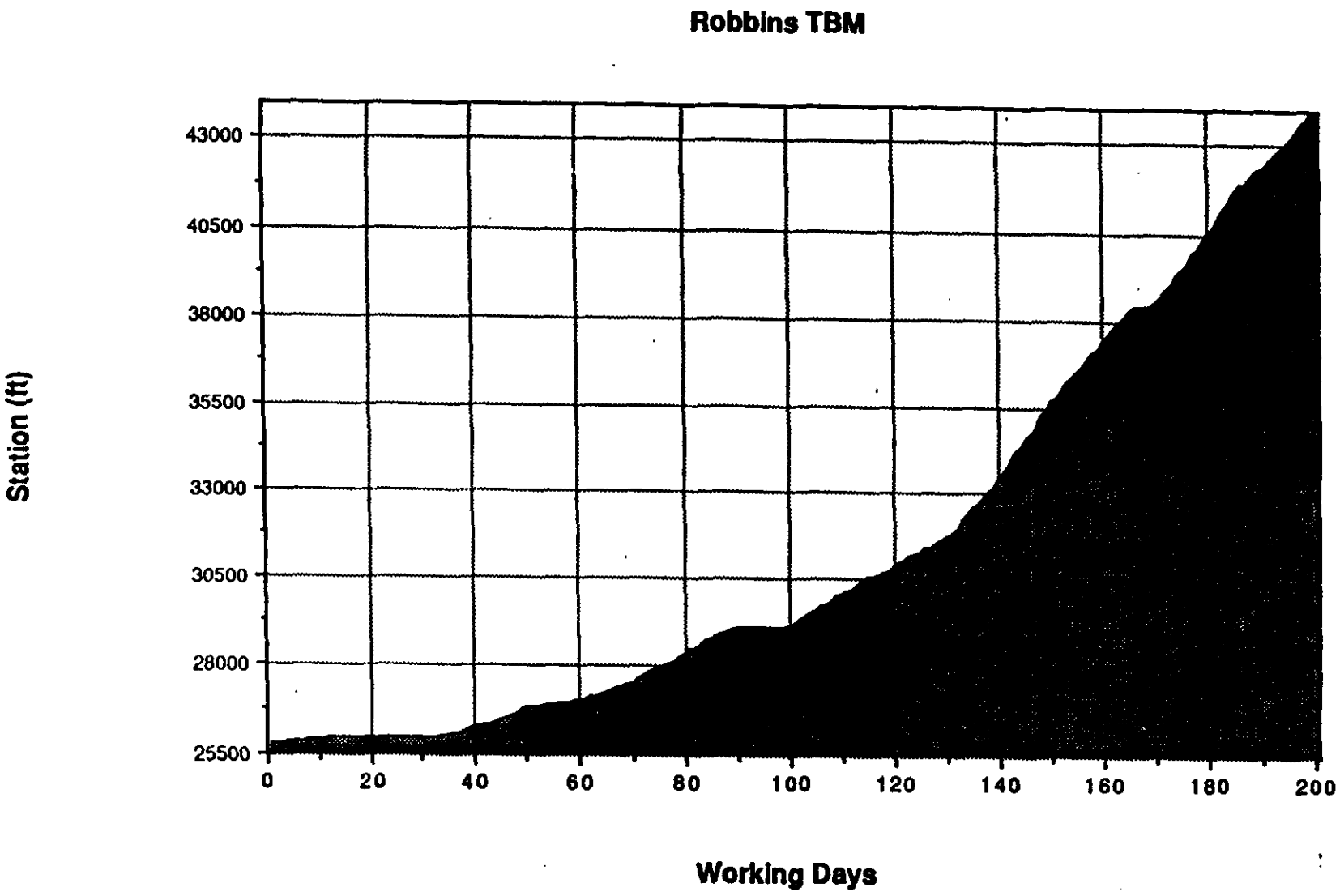
Robbins TBM in Austin Chalk



Robbins TBM in Austin Chalk




Robbins TBM in Austin Chalk
Station (ft)
45000
40000
35000
30000
25000
0
500
1000
1500
2000
2500
3000
3500
4000
Cumulative Shift Hours


Robbins TBM
Station (ft)
43000
40500
38000
35500
33000
30500
28000
25500
0
20
40
60
80
100
120
140
160
180
200
Working Days

Robbins TBM PERFORMANCE

	U %	PR ft/TBM HR	AR ft/Shift HR
START/ CHALK/ HAGGLUND CARS	16.2	13.5	2.2
CHALK/MARL TRAIN	18.2	20.4	3.7
CHALK/ TRAIN	33.9	21.5	7.3
WHOLE JOB	22.9	19.3	4.4

GOVALLE
MAJOR DOWNTIME

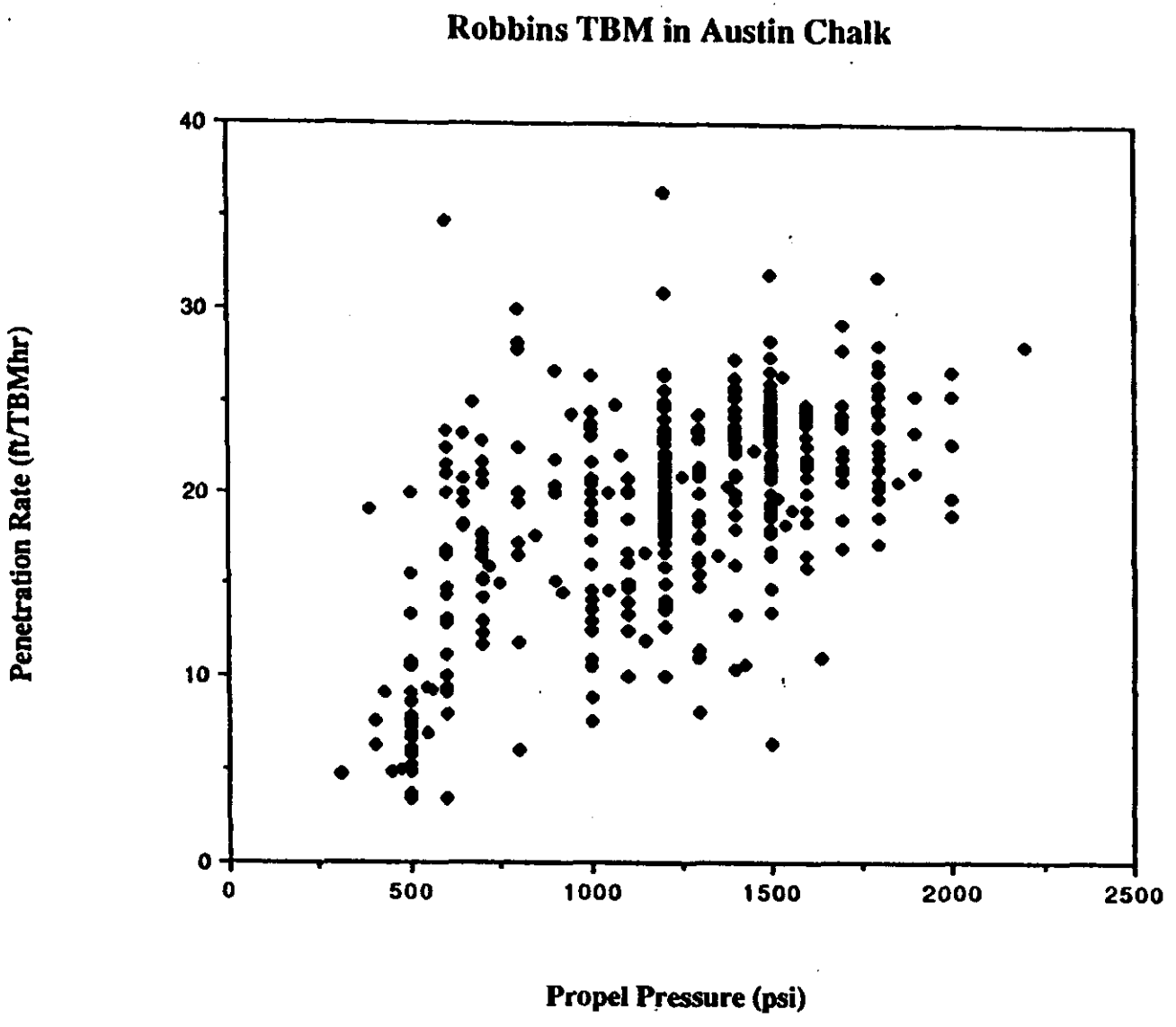
LOVAT MOTORS
LOVAT CUTTER WEAR (CHALK)

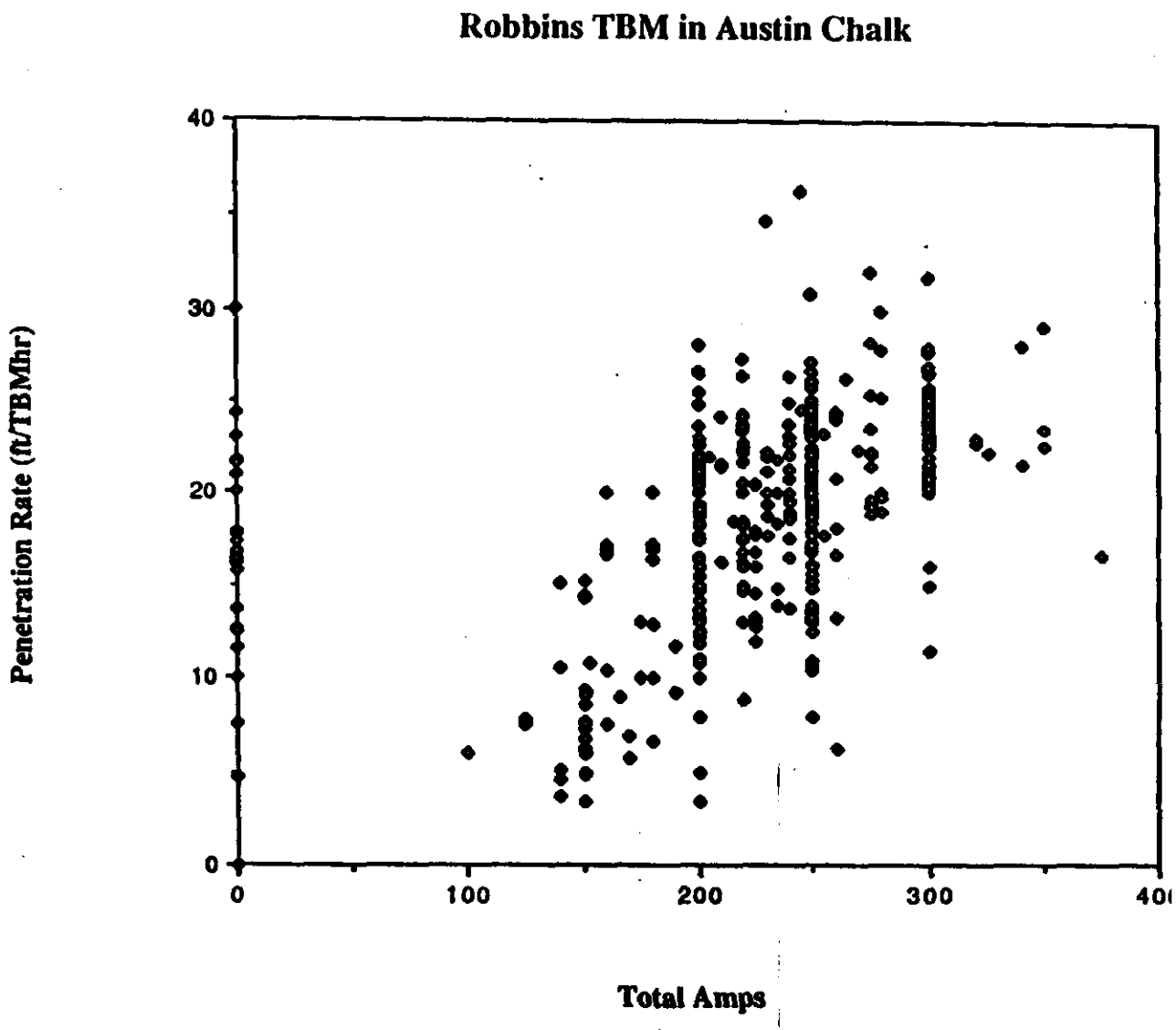
MUCK BOUND - BOTH
DERAILS - BOTH

Robbins GROUND SUPPORT

Govalle Project

	U%	PR (ft/TBM HR)	AR (ft/24 HR Shift Day)
LOVAT in MARL	24	32	183
LOVAT in CHALK	32	11	87
Robbins in MARL	18	20	89
Robbins in Chalk	34	22	175


Robbins TBM in Austin Chalk
Penetration Rate (ft/TBMhr)
40
30
20
10
0
0
500
1000
1500
2000
2500
Propel Pressure (psi)


Robbins TBM in Austin Chalk
Penetration Rate (ft/TBMhr)
40
30
20
10
0
0
100
200
300
400
Total Amps

Information to Date (3/8/88)
for the Govalle Tunnel Project - Robbins TBM

7/1/87 to 3/8/88 Total Project to Date
(Including shifts required for trailing floor installation, Haglund car switch out and crane muck system relocation to a forward shaft)

14114 feet in 432 shifts
32.7 ft/shift
98.0 ft/24 hour day

7/1/87 to 11/2/87 Haglund Car Mucking System
(Including shifts required for trailing floor installation)

3297 feet in 170 shifts
19.4 ft/shift
58.2 ft/24 hour day

11/13/87 to 3/8/88 Crane Mucking System
(Including shifts required for crane muck system relocation to a forward shaft)

10817 feet in 234 shifts
46.2 ft/shift
138.7 ft/24 hour day

For Crane Mucking System Operations:

11/16/87 to 12/31/87	2597 ft in 30 working days = 87 ft/day
1/4/88 to 3/8/88	8256 ft in 44 working days = 188 ft/day

For Crane Operations Shifts with Fairly Complete PBQD Records:

10285 feet
1744.5 shifted hours

5.9 ft/hour average advance rate
141 ft/day average daily advance rate

Instantaneous Penetration Rate at 1500 to 1800 psi thrust system pressure averaging about 3.5 to 4.5 in./min or 0.28 to 0.36 in./cutterhead revolution, at cutterhead assumed rpm=12.63.

Average Utilization	= 54 %
Average Downtime	= 46 %

Note: Per Records, regrip time and time waiting for trains to return is not explicitely included in downtime. Some of each source of time is probably included in both utilization and downtime categories.

Downtime Distribution:

Rail/Rail Repair/Derailments	13 %
Utilities/Install and Repair	7 %
Conveyor Repair/TBM and Backup	6 %
Ground Support and Gripper Cribbing	5 %
Laser and Survey	3 %
TBM Hydraulics Repair	3 %
Bolt Drill Repair	2 %
Electrical Systems Repair/Power	1 %
Repair Crane at Shaft	1 %
Cutter Replacement	1 %

Most Frequent Causes of Downtime:

Derailments and Rail Breakage
Clogged Buckets and Main Beam/TBM Conveyor
Water Accumulation at Heading
Taylor Slack Outfall
Gripper Slippage
Ventilation - Smoke and Dust