The absolute increase in percentage extraction, Δe_a per cent, from a continuous miner pillar compared to that from a drill and blast pillar then becomes

$$\Delta e_a\% = 100[e_{cm} - e],$$

$$\Delta e_a\% = 100\left[1 - \frac{(w - 2\Delta w_o)^2}{C^2} - 1 + \frac{w^2}{C^2}\right].$$

$$\Delta e_a\% = 100\left[\frac{4\Delta w_o(w - \Delta w_o)}{C^2}\right]. \quad (5.8)$$

A plot of the absolute increase in areal percentage extraction versus pillar centre distance, Figure 5.24, shows that the greatest increase is 4,75 per cent at 12 m pillar centre distance, assuming $2\Delta w_o$ is 0,6 m and a bord width of 6,0 m. Thereafter the gain in percentage extraction reduces with increasing pillar width.

Figure 5.25 shows the actual areal percentage extraction for a drill and blast formed pillar and for the equivalent continuous miner fromed pillar, both versus pillar centre distance. The percentage increase in percentage extraction gained through the use of a continuous miner, over the extraction of a conventional pillar, is also plotted on this graph. Figure 5.25 shows that the percentage increase in percentage extraction, over that obtained by drill and blast extraction, is six per cent for an 11 m pillar centre distance and nine per cent for a 31 m pillar centre distance. Although the strength difference between the larger pillar widths mined by the two methods is about one per cent, the nine per cent gain in percentage increase in percentage extraction is due to the low extraction (about 33 per cent) associated with the larger pillar widths.

As an example of the application of the above calculations, assume designed dimensions of

depth to seam	100 m
mining height	3,0 m
bord width	6,0 m
safety factor	1,6.

This results in a drill and blast formed pillar width of 10,1 m and an areal percentage extraction of 60,7 per cent.

Assuming a blast damage zone of 0,3 m, the pillar width of a continuous miner formed pillar would then be 9,5 m and the bord width 6,6 m, giving an areal percentage extraction of 65,2 per cent. This is an absolute increase in extraction of 4,53 per cent.

5.7 LIMITATIONS OF APPLICATION

Use of a continuous miner permits the designed pillar width to be reduced by the extent of the blast damage zone. This can be applied, however, only where a reduction in pillar width does not result in excessive stress concentration over the pillar's edge causing stress-induced fracturing.

The average stress across a pillar is given by the overburden load, L, (calculated by the Tributary Area Theory) divided by the area of the pillar, A.

$$Stress(\sigma) = \frac{L}{A}. \qquad (5.9)$$

Figure 5.26 shows the percentage change in the area of the blast damage zone over the designed pillar area for varying pillar width. The influence of the blast damage zone on average pillar stress concentration reduces rapidly with increasing pillar width and is greatest for pillars less than 6,0 m in width. Stress-induced fractures at the pillar's edge could result in the instability of smaller pillars, because of the reduction in area leading to continued slabbing of the sidewall.

Also, as the depth of mining increases the stress concentration over the pillar's edge approaches the material strength of the coal. Table 5.4 shows the average pillar stress over pillars mined to a safety factor of 1,6 assuming a pillar height of 3,0 m and a bord width of 6,0 m.

Table 5.4 Average Stress Over Pillars Mined to a Safety Factor of 1,6.

Depth H (m)	Pillar Width w (m)	Average Stress MPa
50	6,0	5,00
100	10,1	6,32
150	14,5	7,46
200	19,4	8,53
250	25,0	9,56
300	31,3	10,60

The stress profile across a pillar is such that near the edge of the pillar the stress has a peak. (Refer to Figure 5.13). If the peak stress exceeds the material strength, stress-induced fracturing occurs, the load carrying capacity of the fractured slab is reduced and the peak stress progresses towards the pillar's centre. The stress is then redistributed over a wider area and the peak stress is reduced. Further fracturing occurs until the "failed" slabs are in an equilibrium with the load acting across the pillar. This process of fracturing reaches an equilibrium in wider pillars because of the failed material carrying part of the load and because of the frictional forces acting on the roof and floor contact.

Maximum benefit, in terms of increased extraction when using a continuous miner, occurs between pillars of a width greater than 5,0 m and at depths of not more than approximately 175 m at which point the onset of stress-induced fracturing occurs.

The use of a continuous miner results in improved mining conditions as a result of smoother sidewall profiles and greater roof control at depths in excess of 175 m. Because of stress-induced sidewall slabbing, however, the benefits of increased extraction are reduced at these depths.

5.8 ESTIMATED SAVINGS

In South African collieries approximately 17 million tons of coal were mined by continuous miners in bord and pillar panels in 1985. This represents 11,3 million cubic metres of coal extracted by continuous miners. Assuming an average mining height of 3,0 m and the specific gravity of coal to be 1,5 the equivalent area of the 17 million tons of coal would be 3,78 million squared metres. Again assuming the average pillar dimensions for a 1,6 safety factor production panel at a depth of 100 m to be 10,1 m in width, an areal percentage extraction of 60,1 percent would be equivalent to the 3,78 million squared metres. Using a continuous miner would allow a reduction in the pillar width by 0,6 m and an increase in the bord width by the same amount. This would result in an areal percentage extraction of 65,18 per cent or 4,06 million squared metres. Multiplying this figure by the assumed average mining height of 3,0 m and by the specific gravity of coal of 1,5, the potential increase in extractable reserves could be about 1,28 million tons per annum.

This figure may be an upper estimate as not all continuous miner formed pillars are mined to a safety factor of 1,6 and the assumed average dimensions may be inaccurate; it however indicates the potential benefit of exploiting the increased strength of a continuous miner formed pillar. Since the strength of the smaller continuous miner formed pillars will be equivalent to the blast damaged drill and blast formed pillar, increased extraction will result without a reduction in the stability of the geometry.

5.9 CONCLUSIONS

The investigation showed that the fractured side of a pillar is the result of the weakening effect of blasting on a pillar's side and is correctly termed the blast damage zone. This zone extends 0,25-0,30 m into a coal pillar side.

Slabbing in a conventional drill and blast section reduces the pillar width by up to 0,5 m over a period of time and blast-induced fractures extend 0,1-0,2 m into the sidewall of a pillar after slabbing has occurred.

The pillar formed by a continuous miner to the same designed dimensions as a drill and blast formed pillar has greater strength due to the absence of the blast damage zone. Therefore, when mining by continuous miner, the designed pillar width can be reduced by the extent of the blast damage zone from that of a drill and blast pillar without increasing the risk of pillar failure. When calculating continuous miner formed pillar dimensions, a fixed reduction in pillar width, rather than a fixed reduction in safety factor, is used.

The increase in strength of a continuous miner formed pillar over that of a drill and blast formed pillar is greatest for small pillar dimensions, 5,4 per cent at 5,0 m width, and rapidly reduces with an increase in pillar width, 1,0 per cent at 30 m width. The increase in percentage extraction is greatest at 12 m pillar centres, 4,75 per cent, and declines with an increase in pillar width to a 4,2 per cent increase at 19 m centres. The increase in extraction, expressed as a percentage over actual extraction, increases with an increase in pillar width from 6,0 per cent at 11 m centres to approximately 9,0 per cent at 31 m centres. Based on the 1985 production figures, approximately one million tons of coal could be added to the country's reserves annually by utilizing the increased strength of a continuous miner formed pillar.

The limitation of this method is that stress-induced damage could result in pillar failure in pillars less than 5,0 m wide. Stress-induced fractures occur in pillars mined to a safety factor of 1,6 at a depth of about 100 m and slabbing occurs on pillars in workings in the region of 175 m depth.

This design method is being used to design continuous miner formed panels in bord and pillar workings at Matla Colliery and, over the past three years, an estimated 4,5 per cent increase in extraction has been obtained.

At Khutala Colliery, according to Bradbury and Hill (1989), the design method described in this chapter has been responsible for adding up to an estimated 32 million tons to the colliery's reserves. This has been achieved through both the reduction in pillar widths required and, as a consequence, the non-superimposition of panel pillars in the No. 2 and No. 4 Seams.

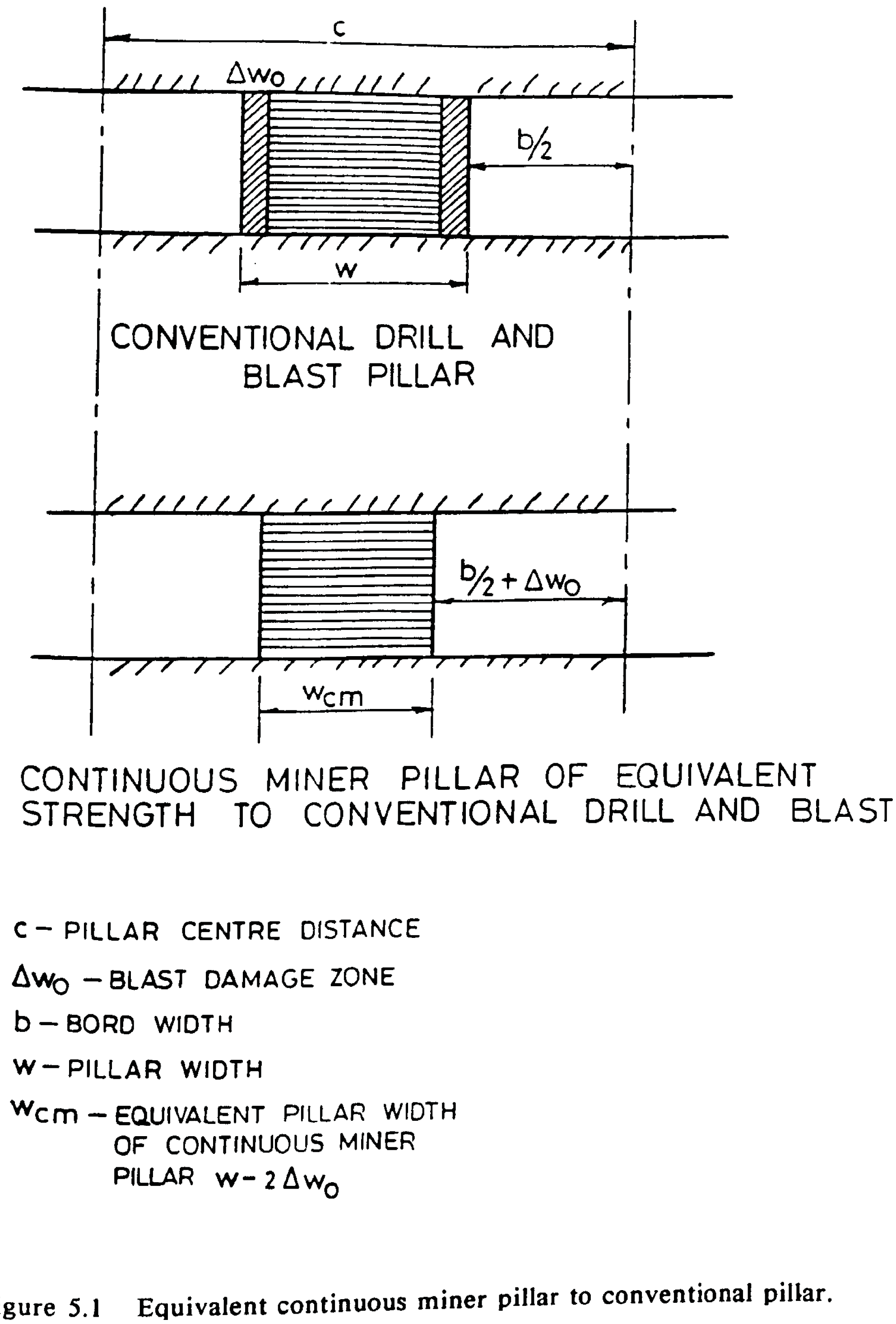

Figure 5.1 Equivalent continuous miner pillar to conventional pillar.

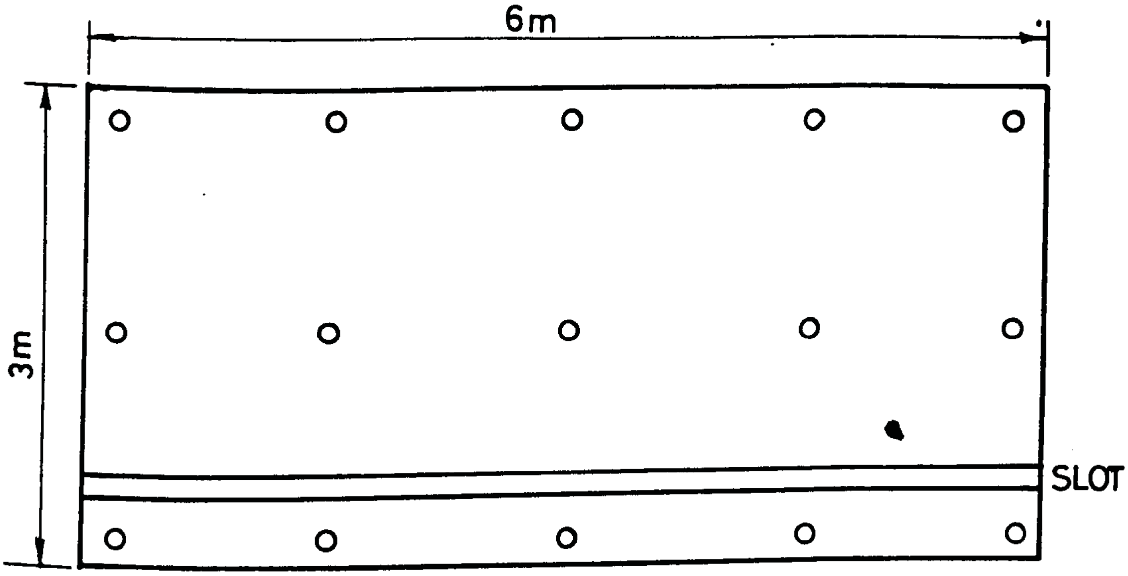

Figure 5.2 Typical drilling pattern of conventional drill and blast face.

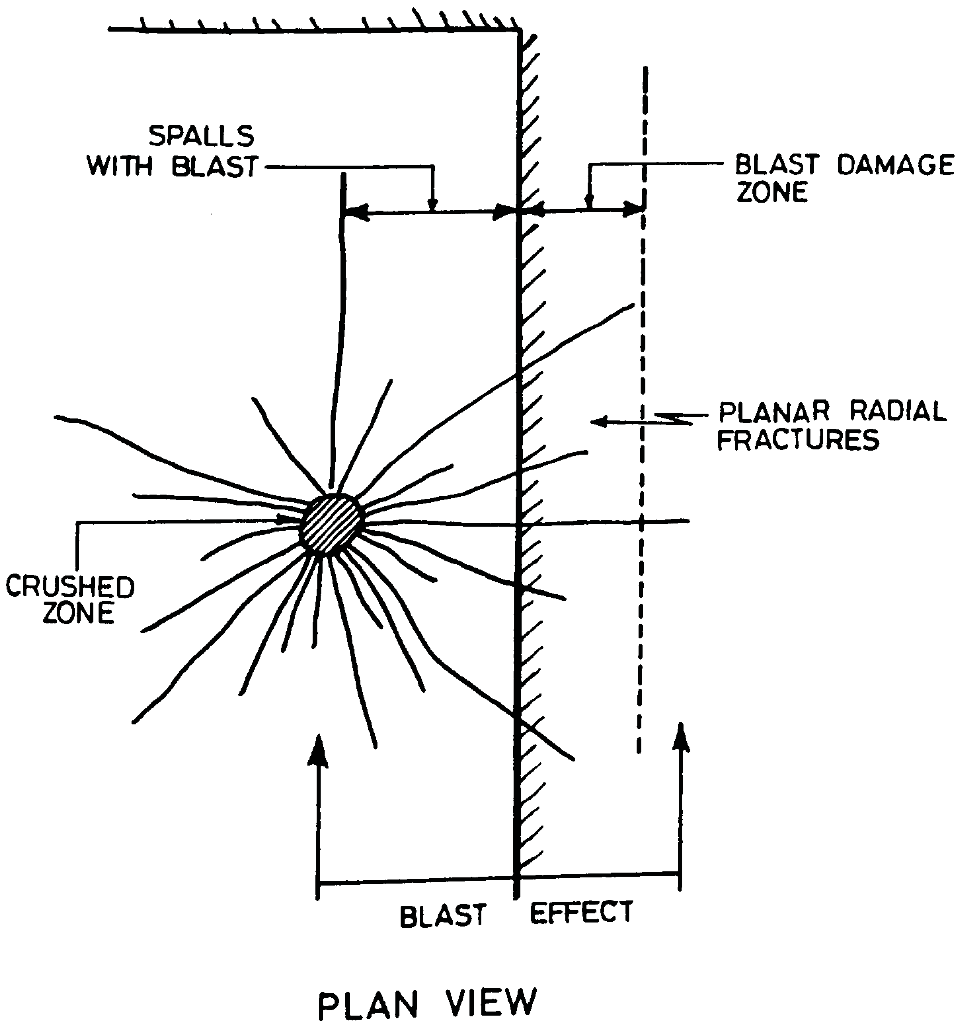

Figure 5.3 Zones of blast damage around a blasthole.

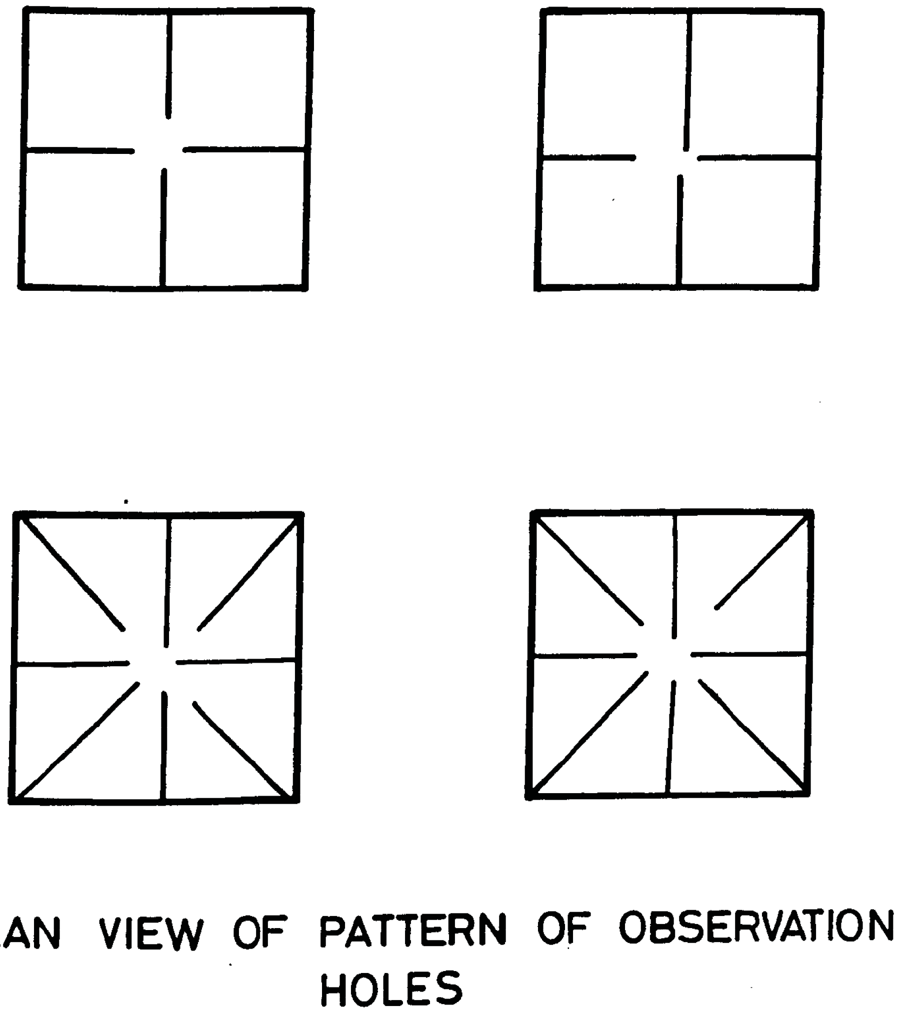

Figure 5.4 Pattern of observation holes.

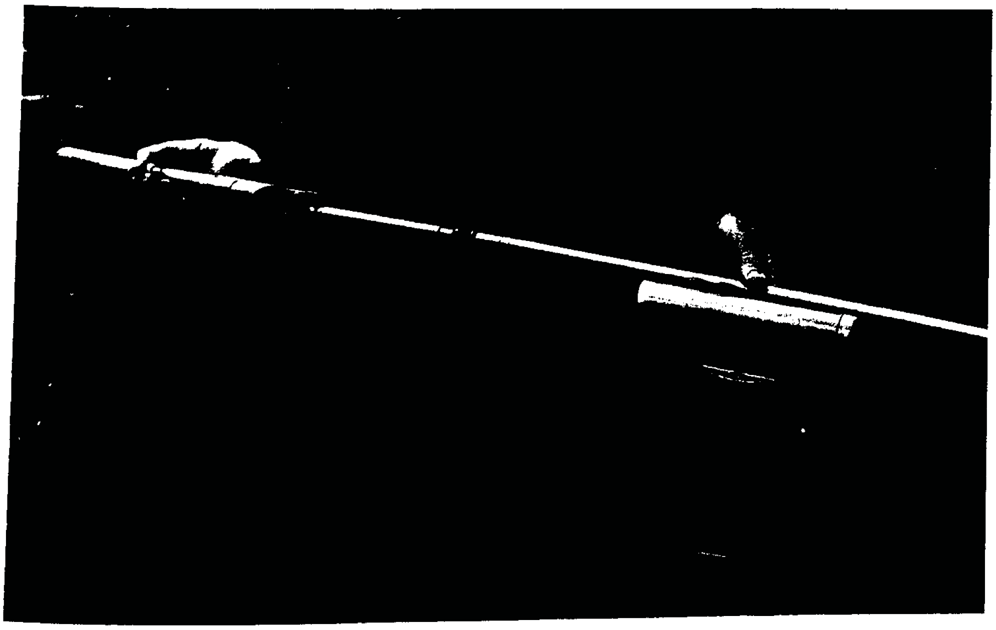

Figure 5.5   Chamber of Mines Research Organization petroscope.

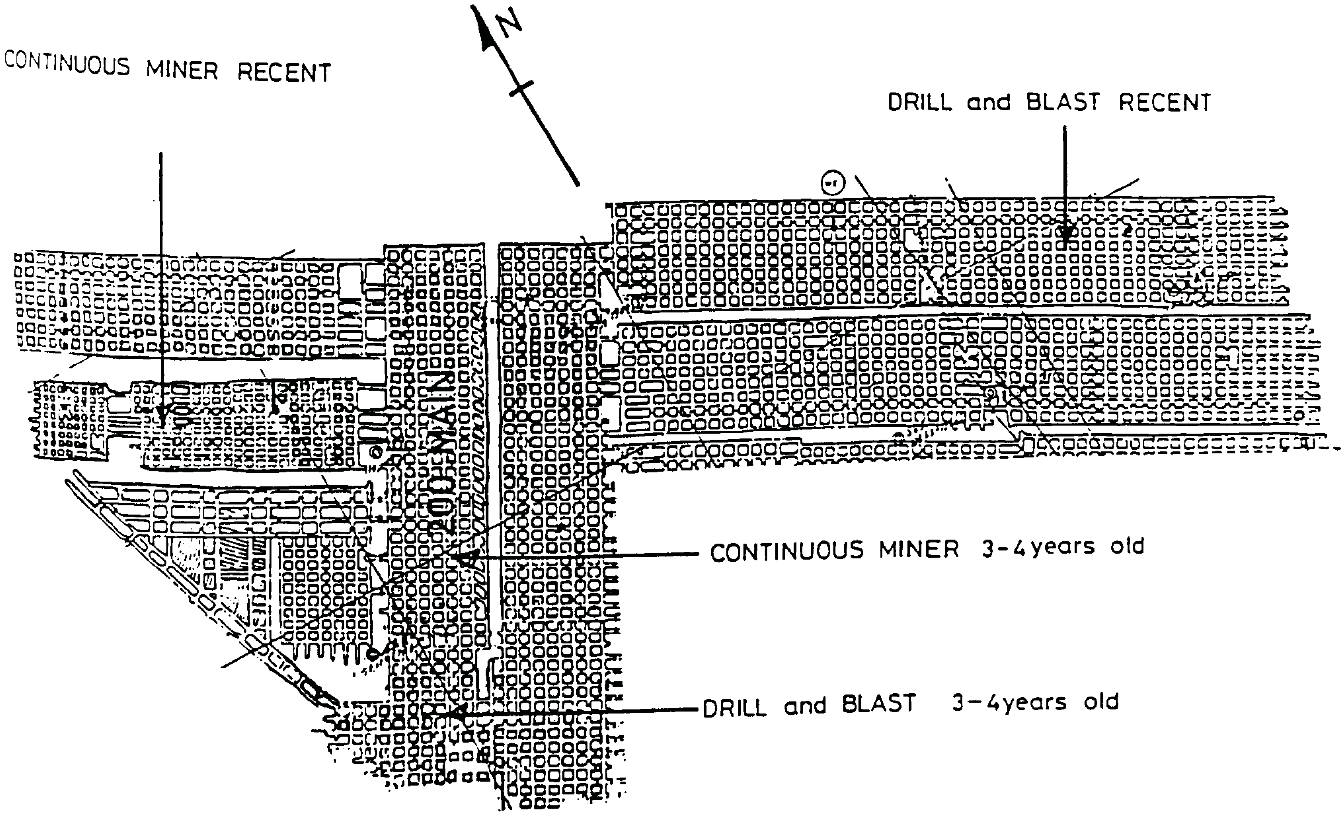

Figure 5.6 Panels investigated at Cornelia Colliery.

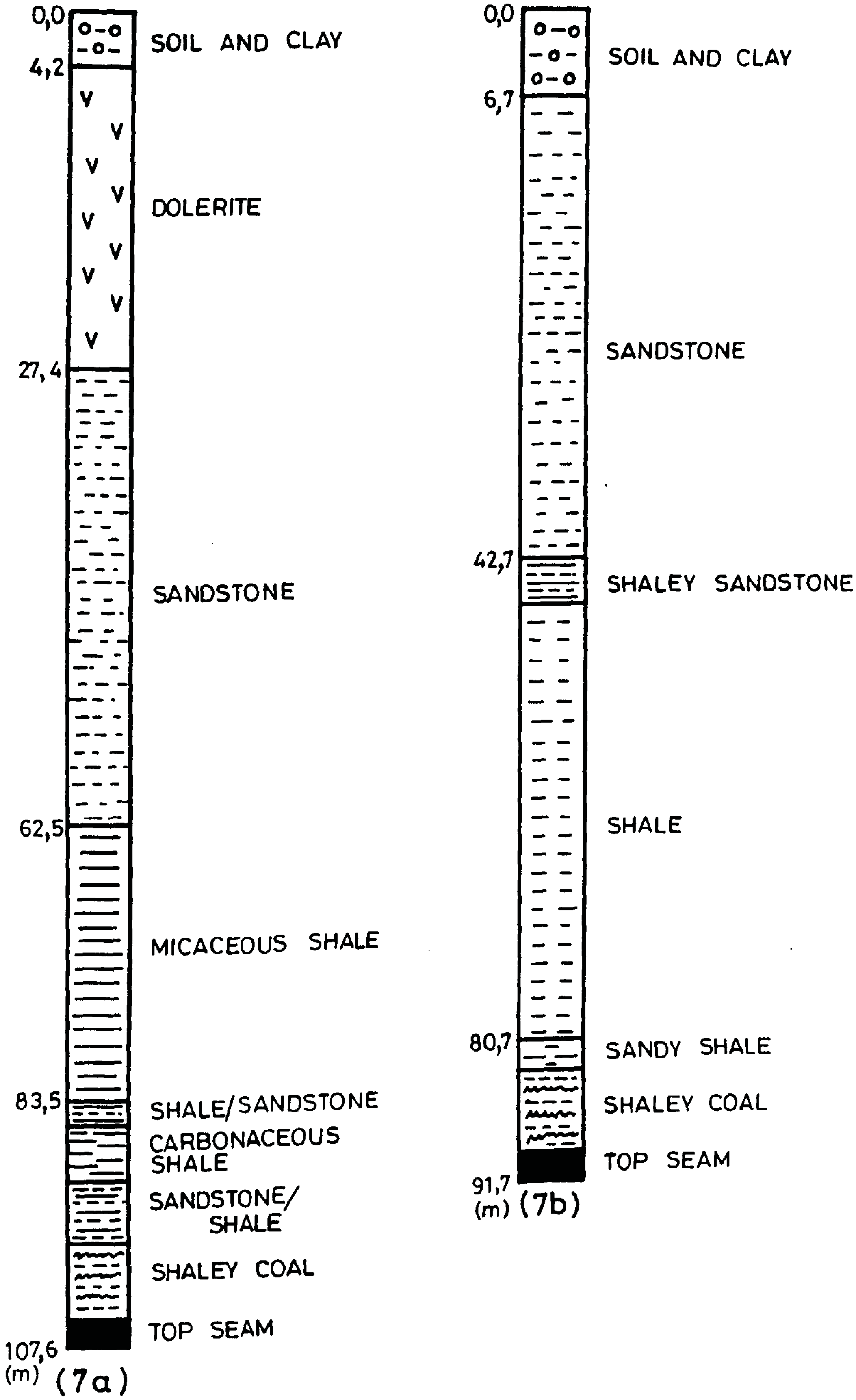

Figure 5.7 Geology of Cornelia Colliery.

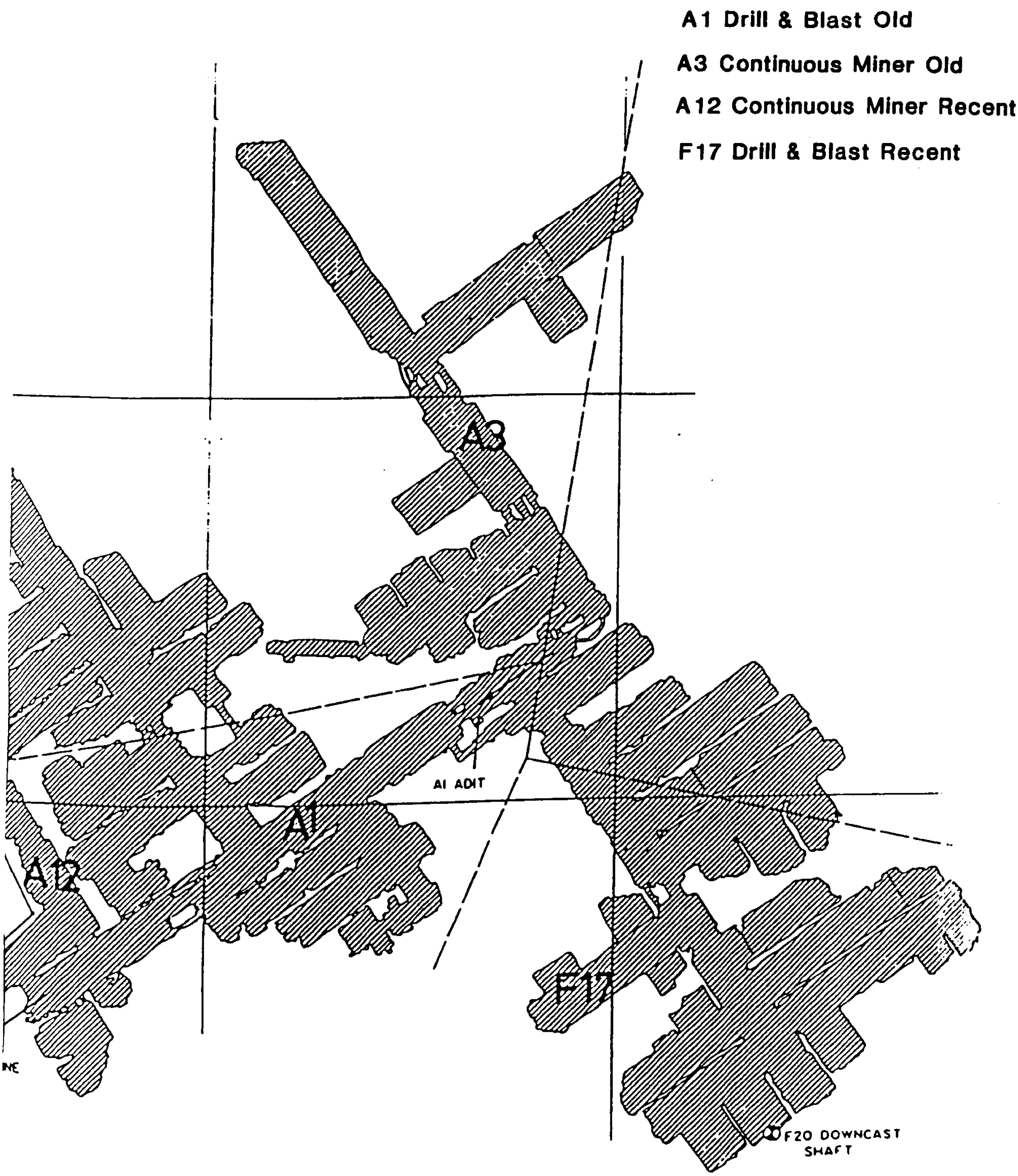

Figure 5.8 Panels investigated at Kriel Colliery.

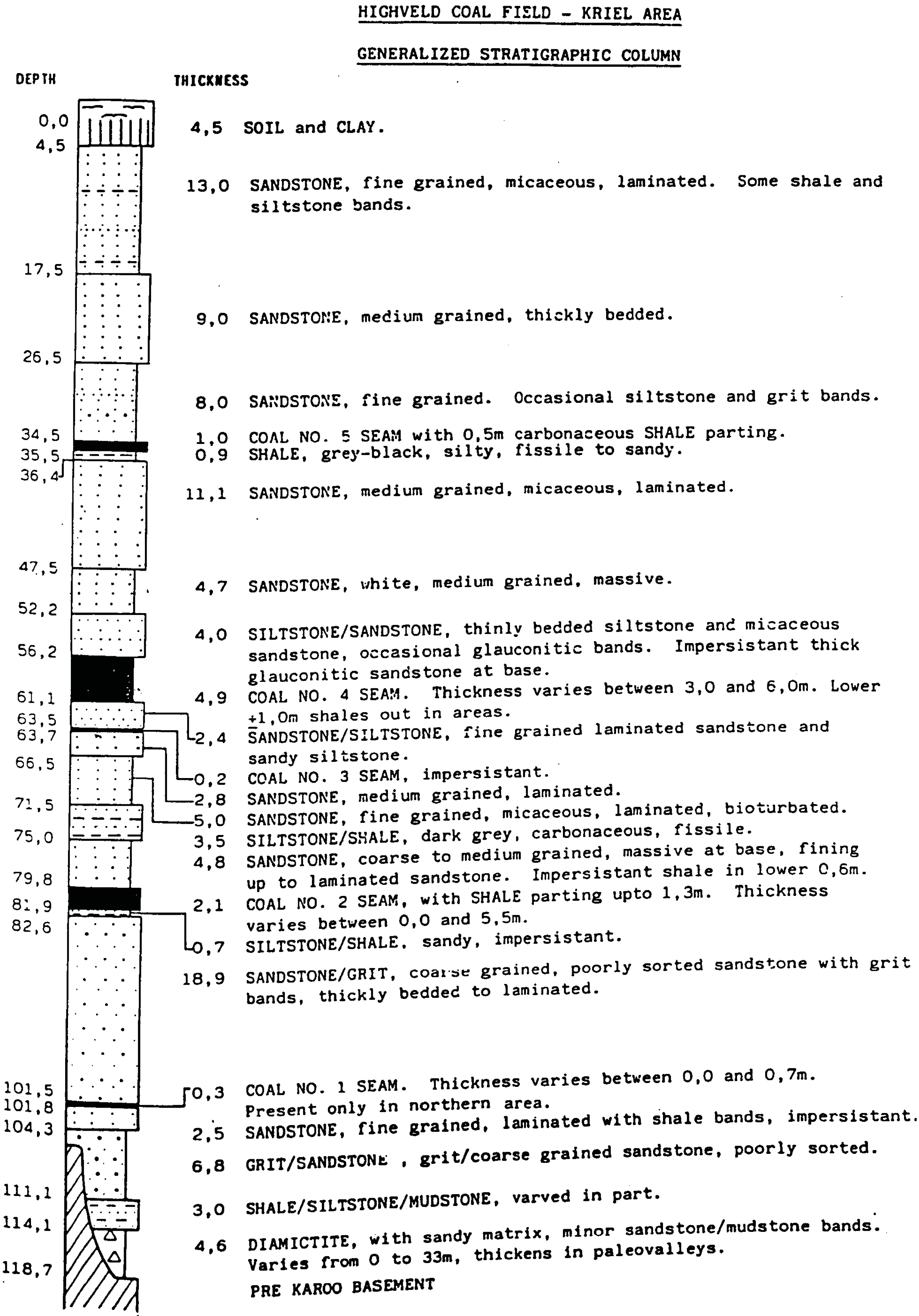

Figure 5.9 Geology of Kriel Colliery.

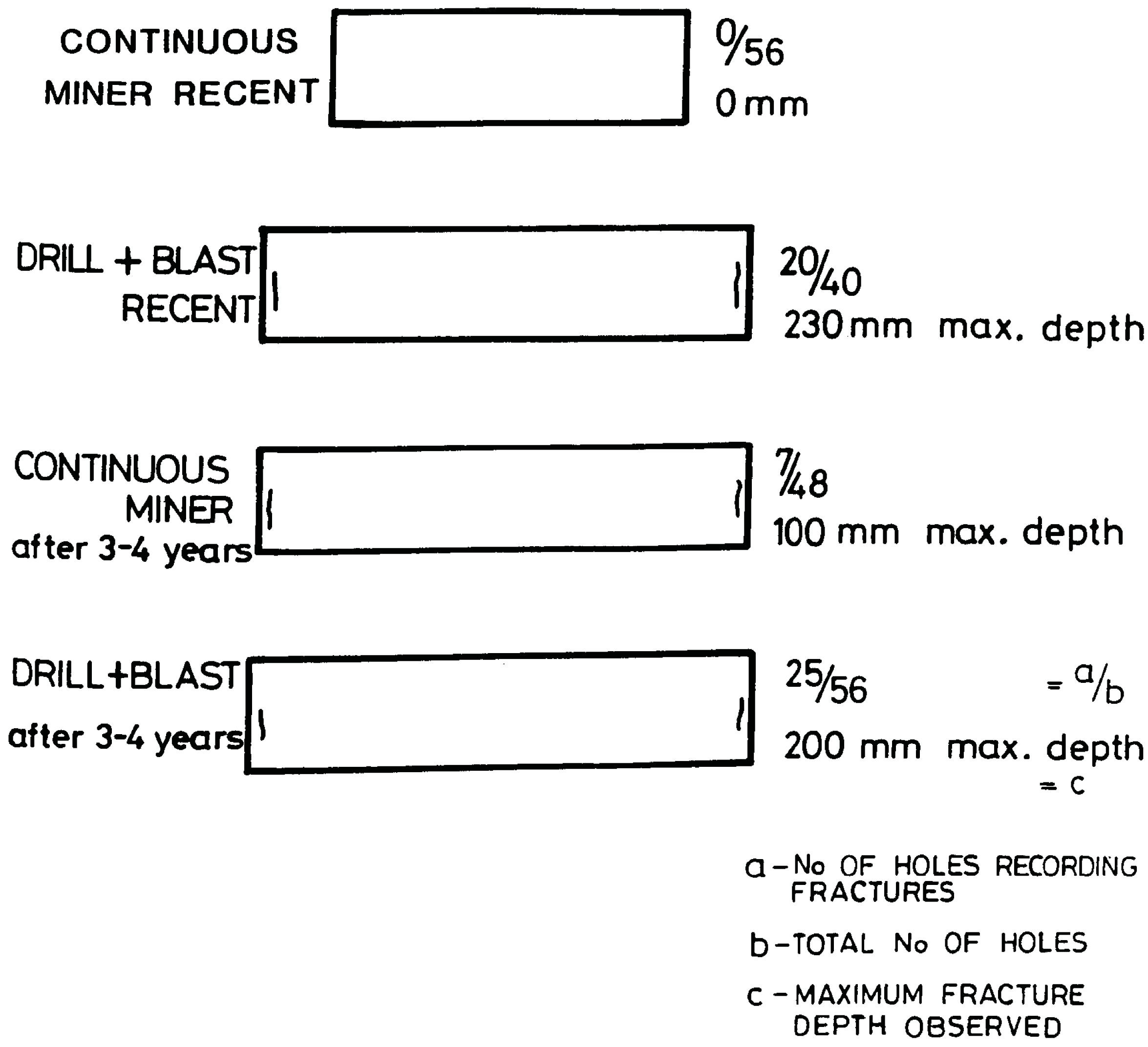

Figure 5.10 Depth and frequency of fractures observed, Cornelia Colliery.

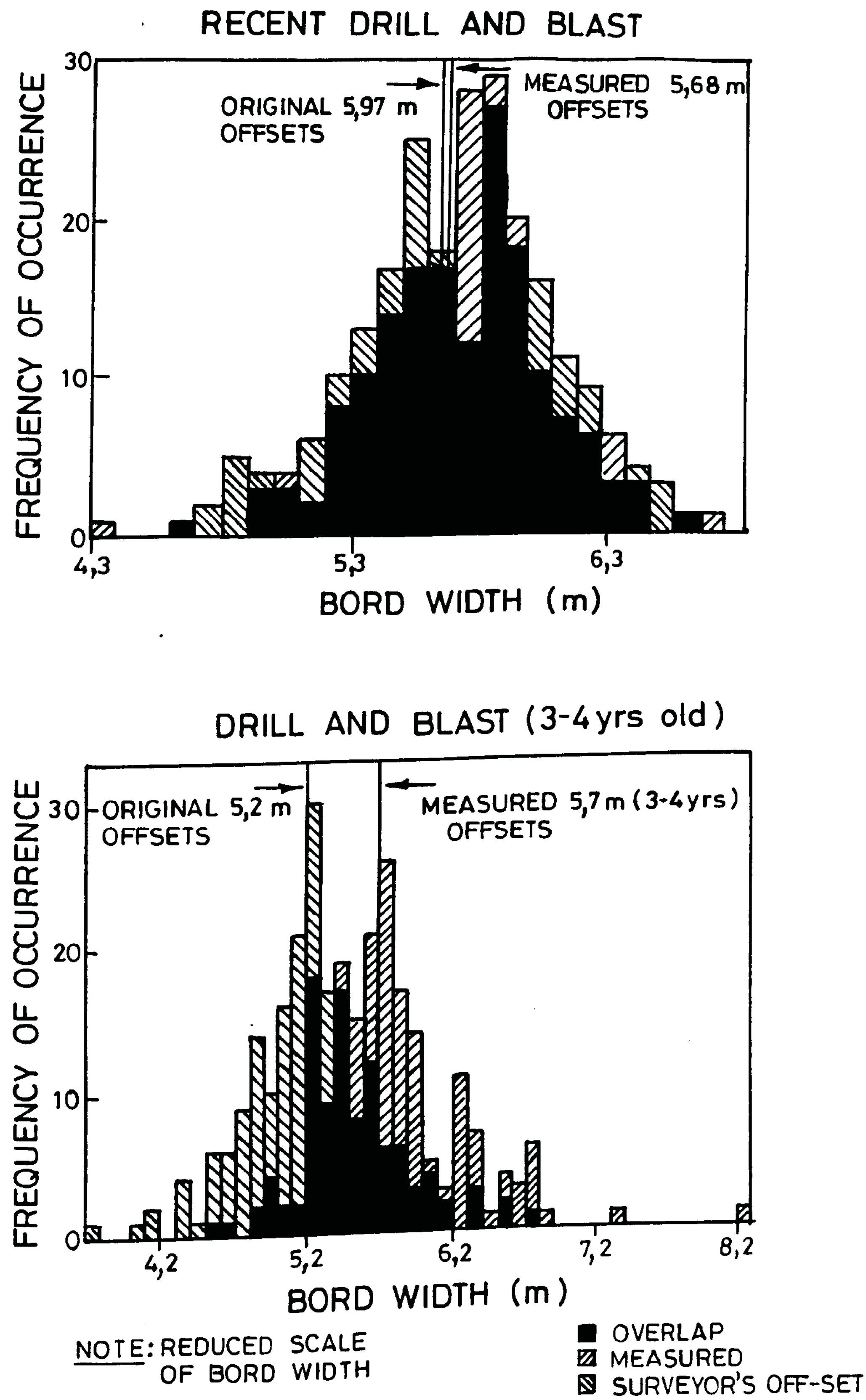

Figure 5.11 Original offsets and measured bord widths in recent and previous drill and blast sections, Cornelia Colliery.

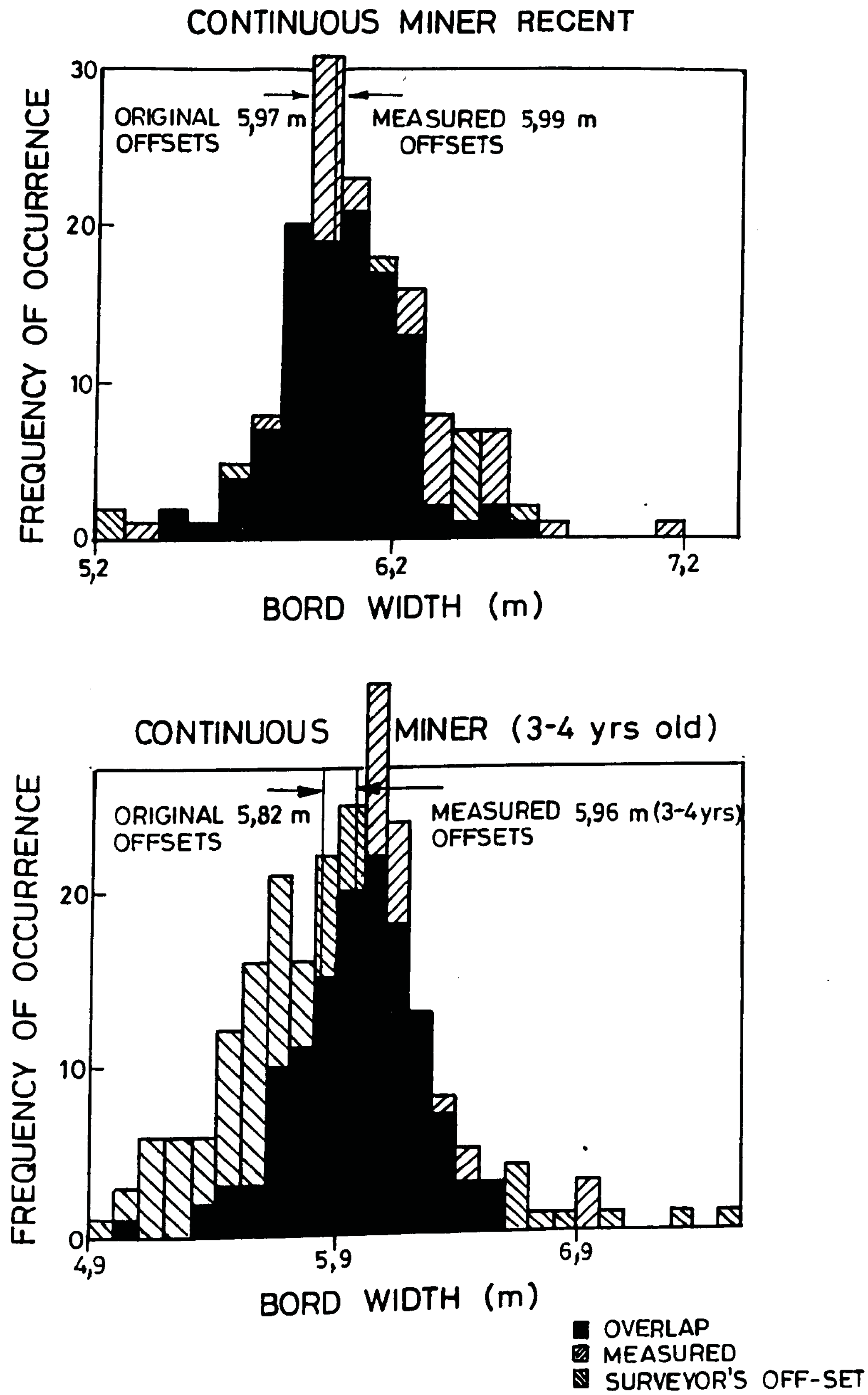

Figure 5.12 Original offsets and measured bord widths in recent and previous continuous miner sections, Cornelia Colliery.

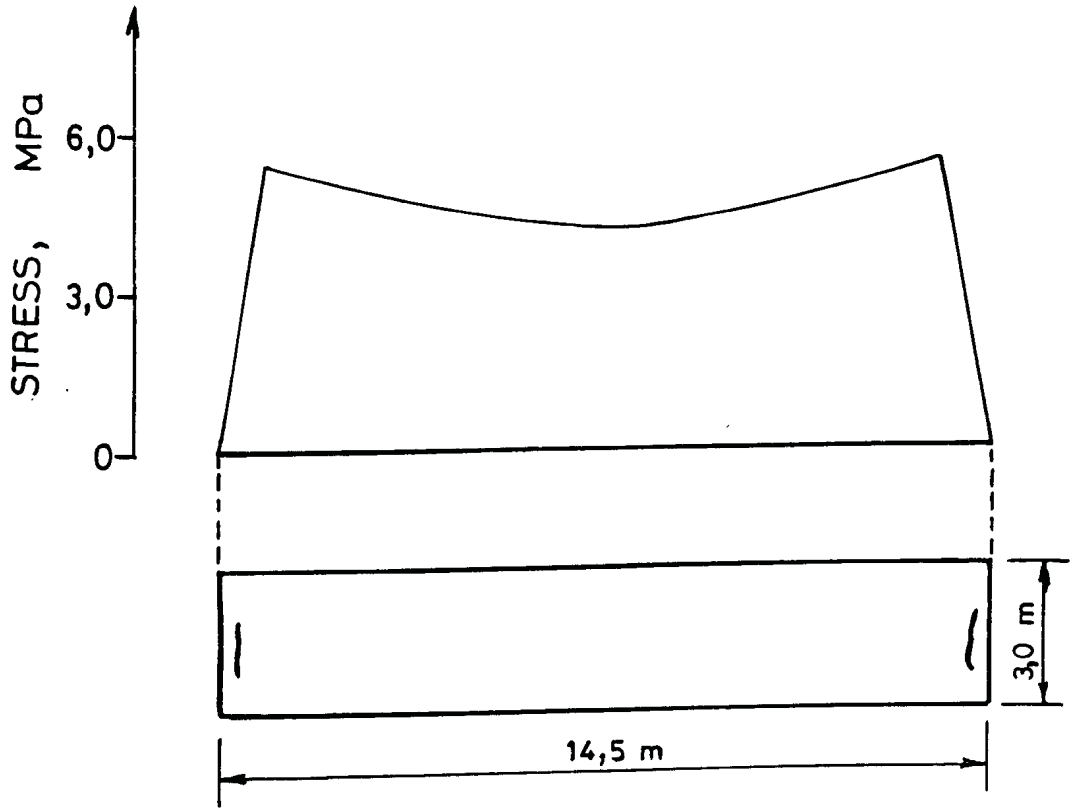

Figure 5.13 Stress and observed fractures in 3-4 year old conventional section, Cornelia Colliery.

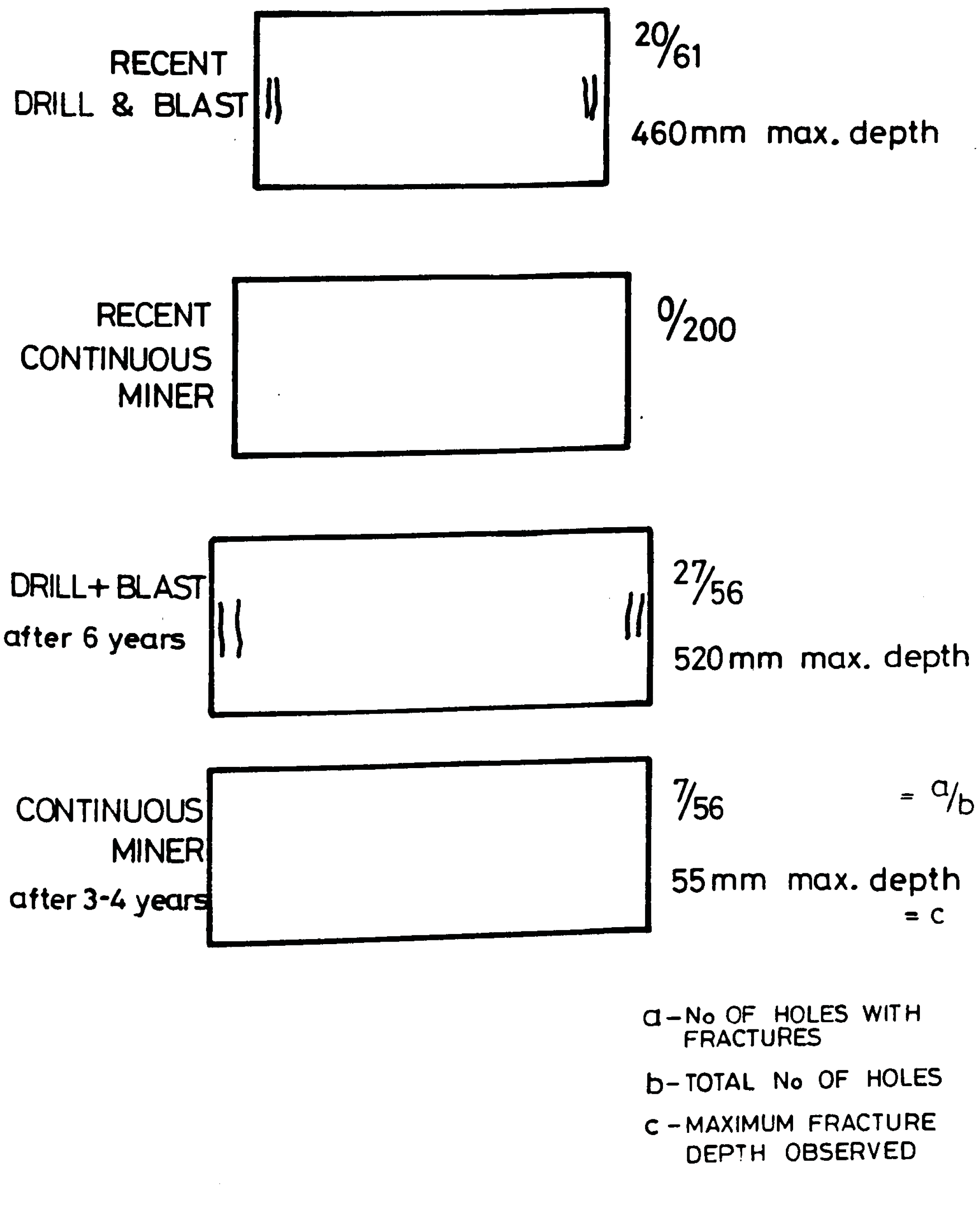

Figure 5.14 Depth and frequency of fractures observed in panels, Kriel Colliery.

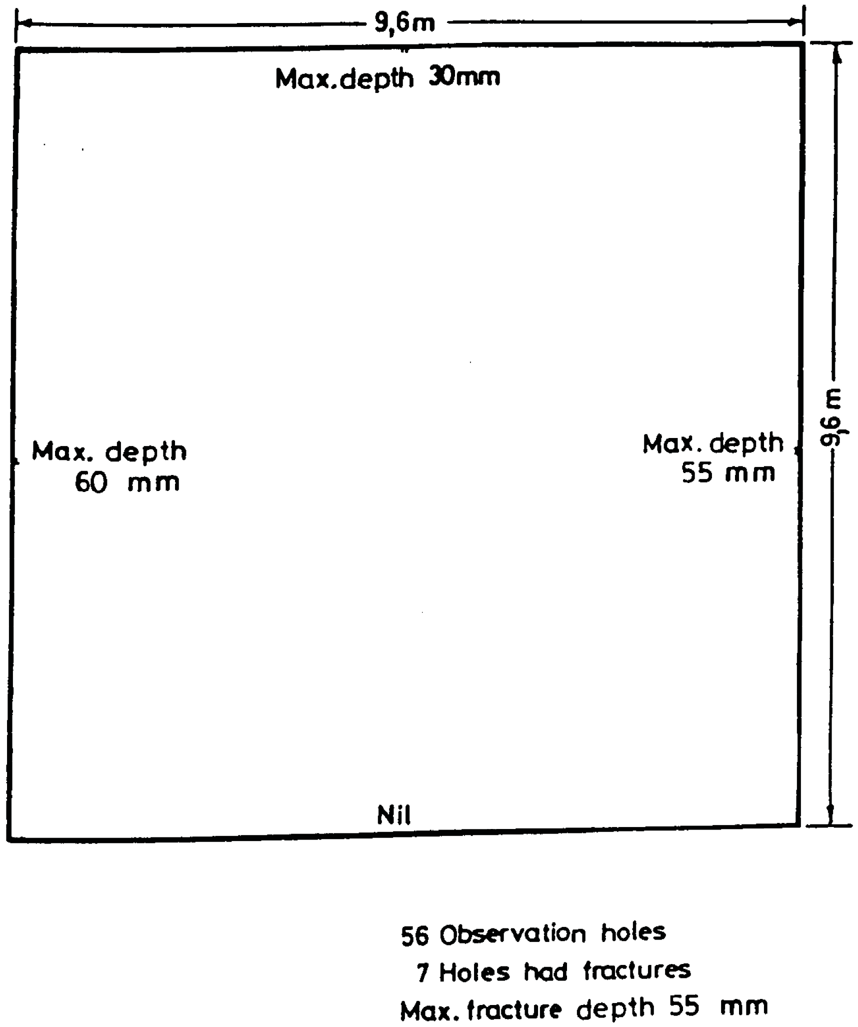

Figure 5.15 Fracture observations in continuous miner section 3-4 years old, Kriel Colliery.

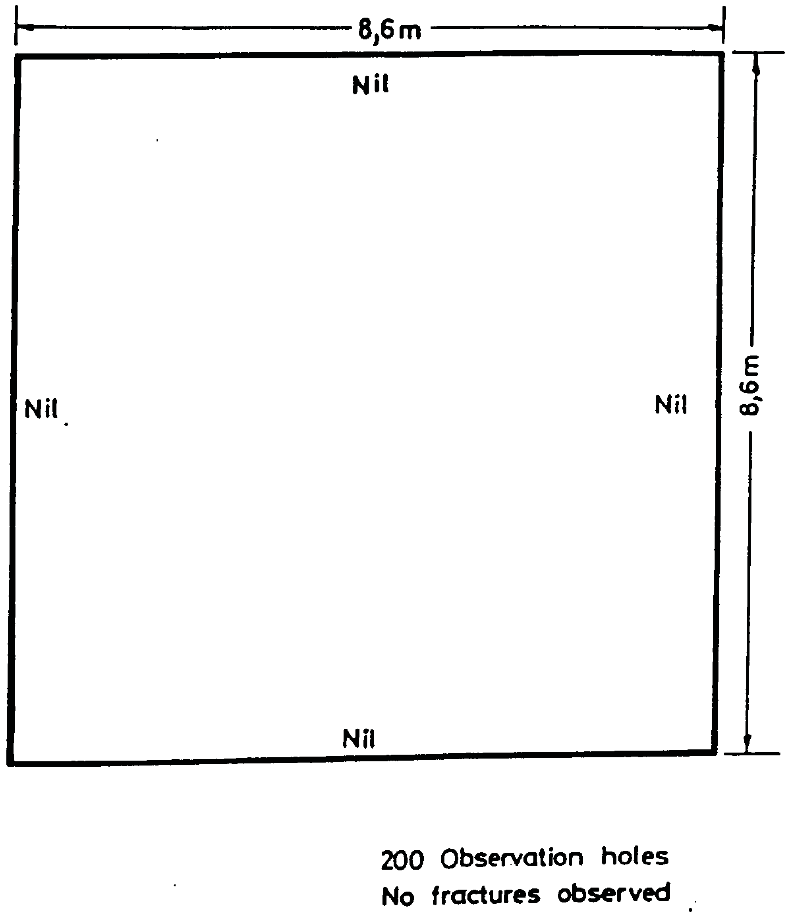

Figure 5.16 Fracture observations in recent continuous miner section, Kriel Colliery.

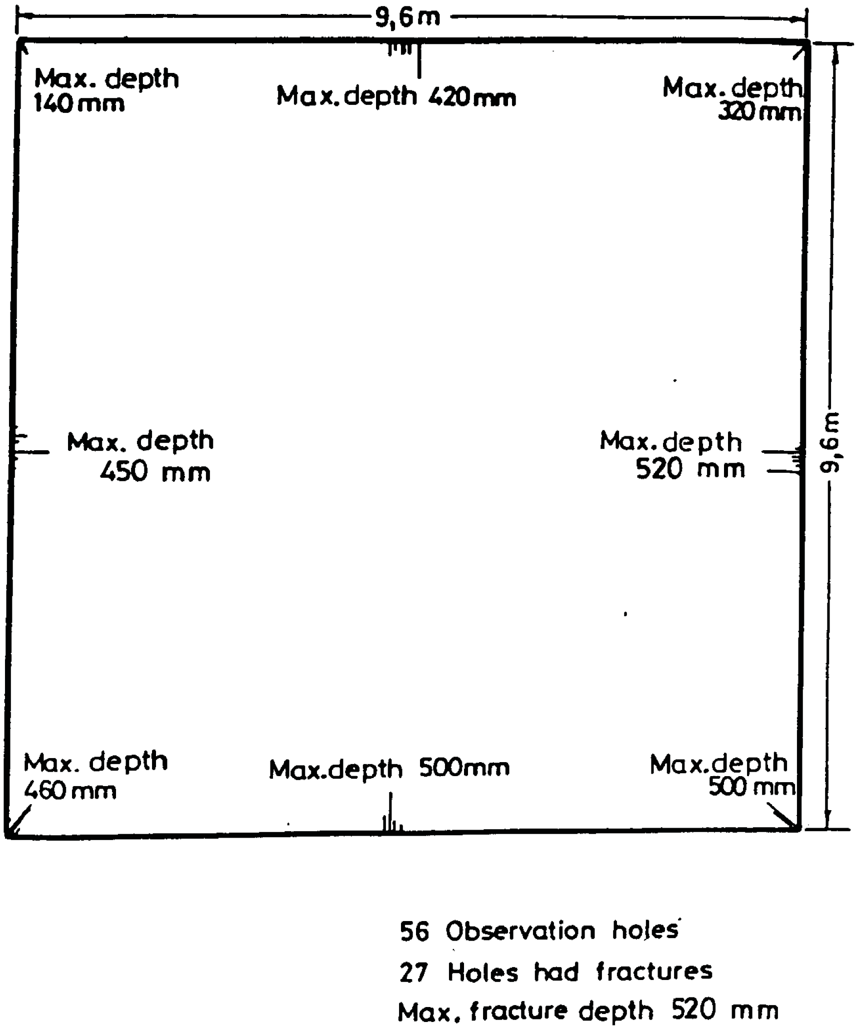

Figure 5.17 Fracture observations in drill and blast section 6 years old, Kriel Colliery.

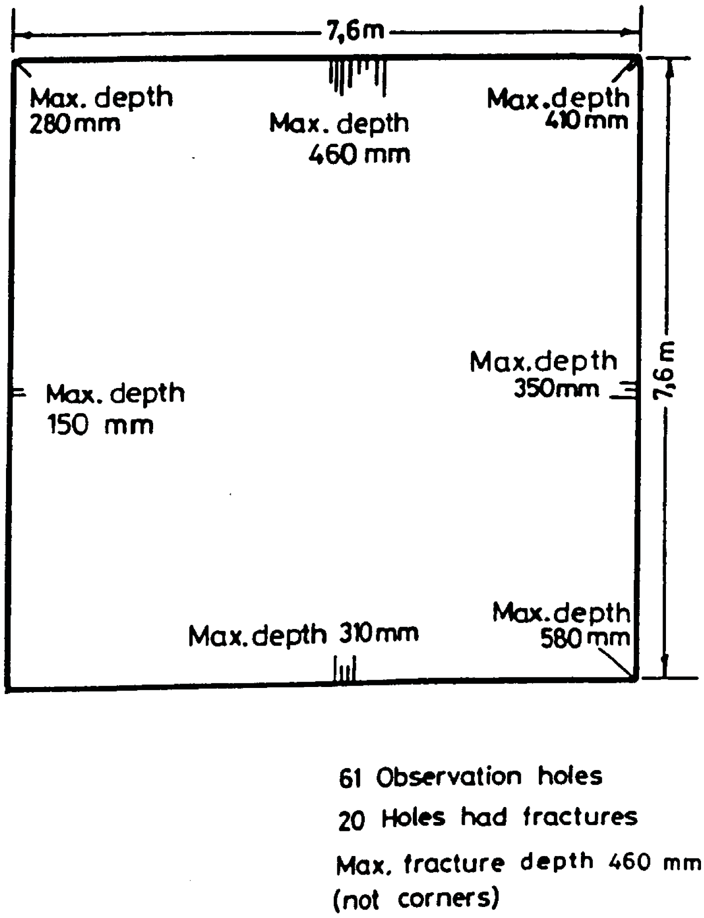

Figure 5.18 Fracture observations in recent drill and blast section, Kriel Colliery.

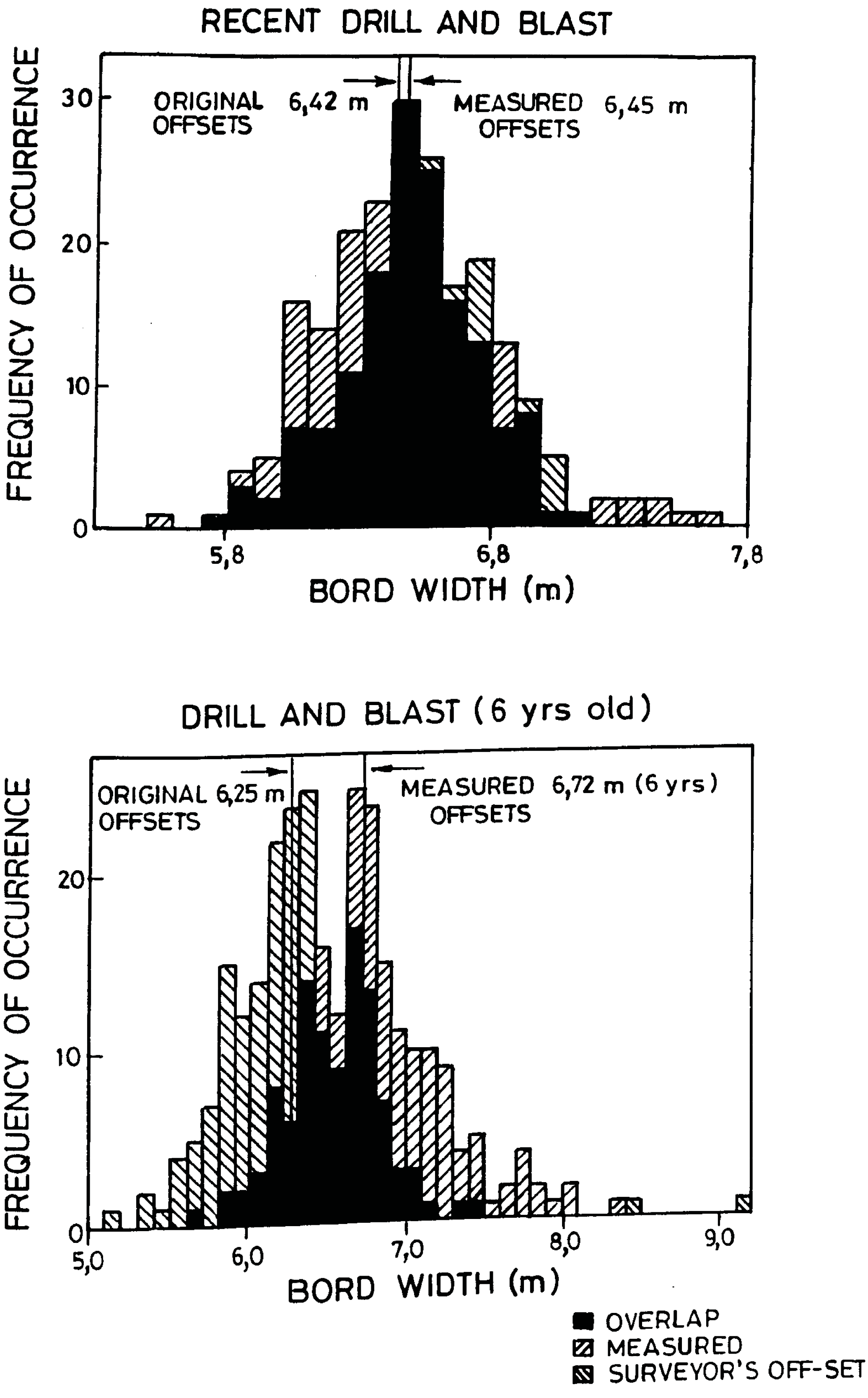

Figure 5.19 Original offsets and measured bord width in recent and previous drill and blast sections, Kriel Colliery.

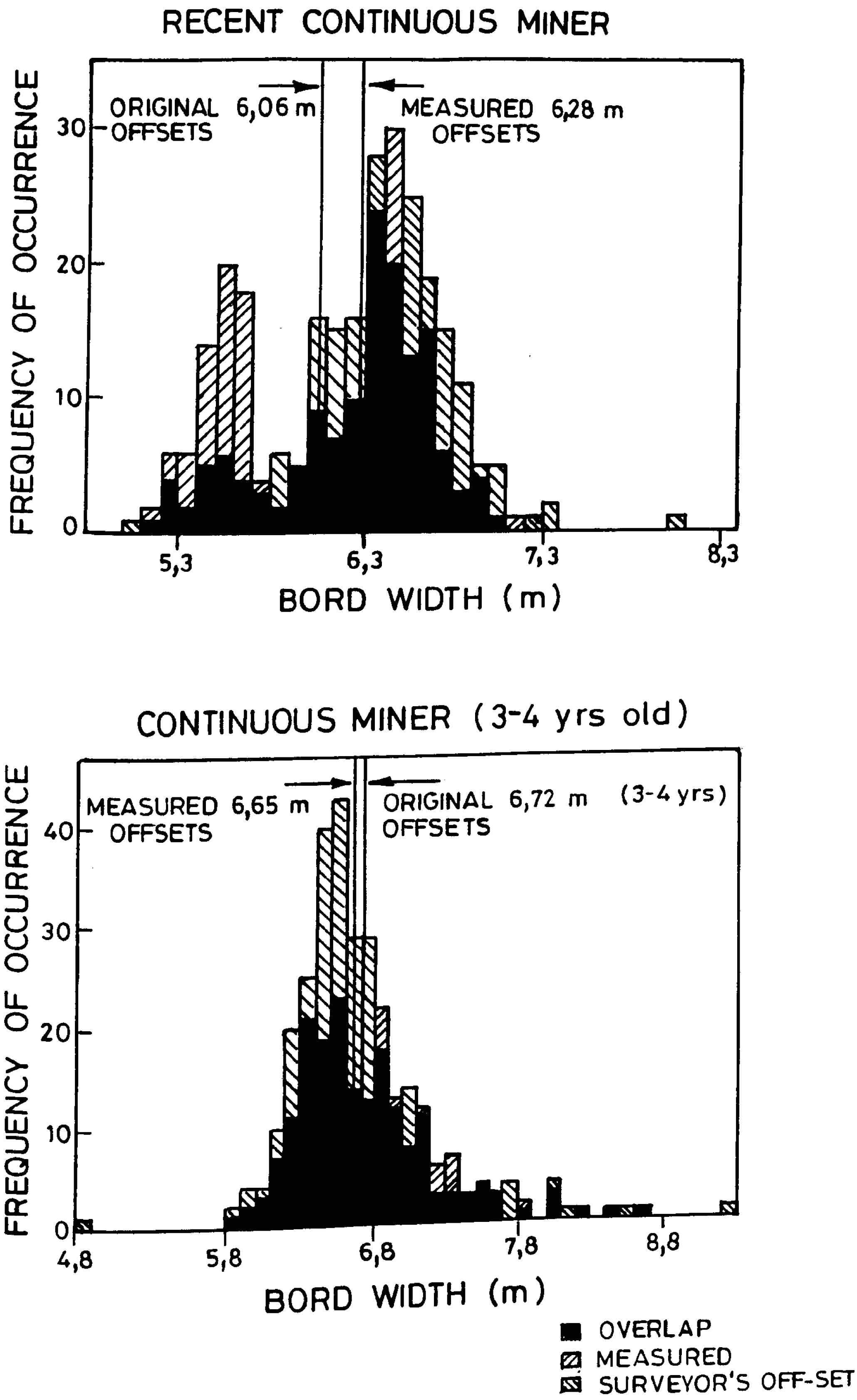

Figure 5.20 Original offsets and measured bord width in recent and previous continuous miner sections, Kriel Colliery.

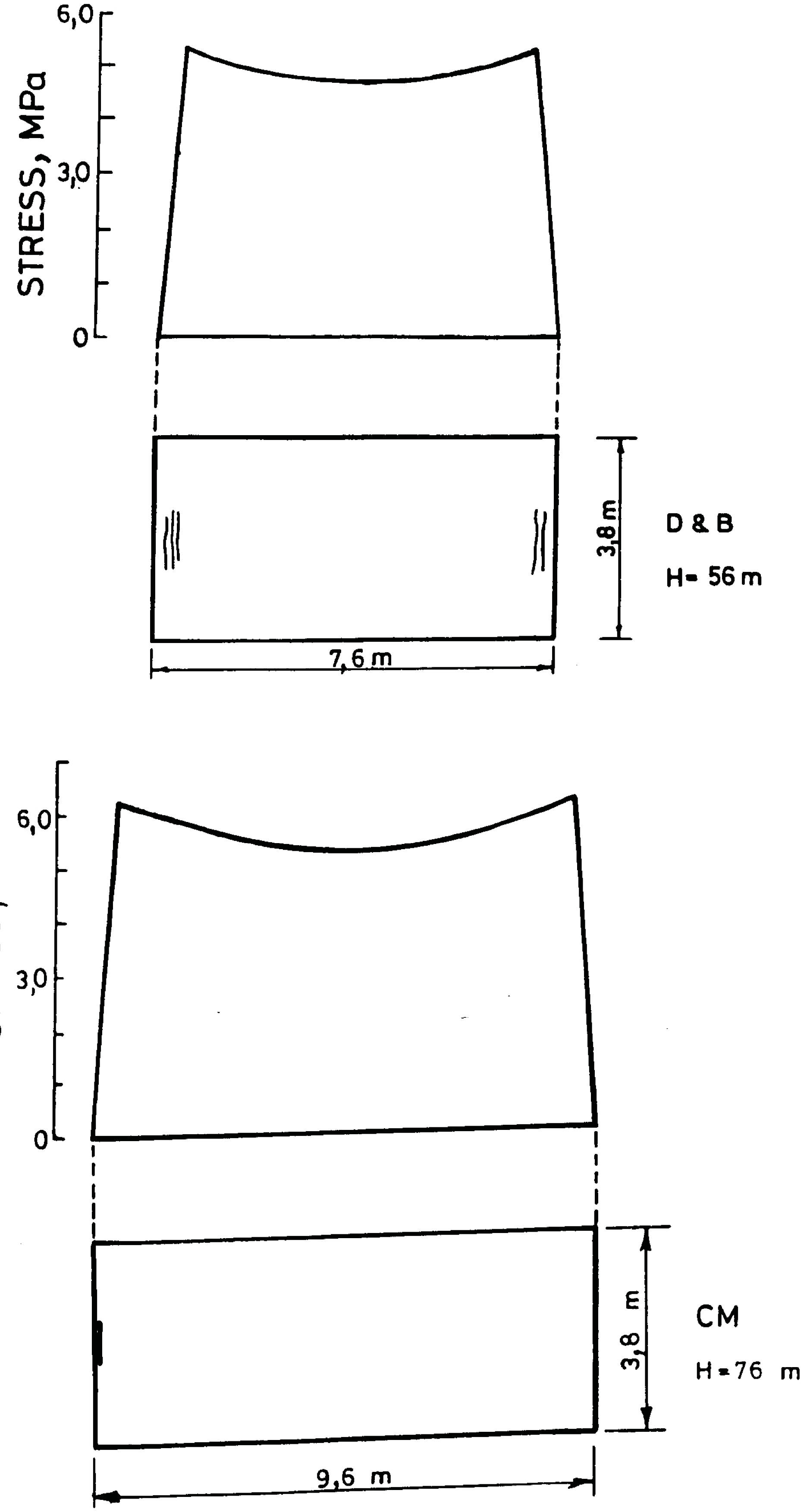

Figure 5.21 Stress and observed fractures over range of pillar dimensions, Kriel Colliery.

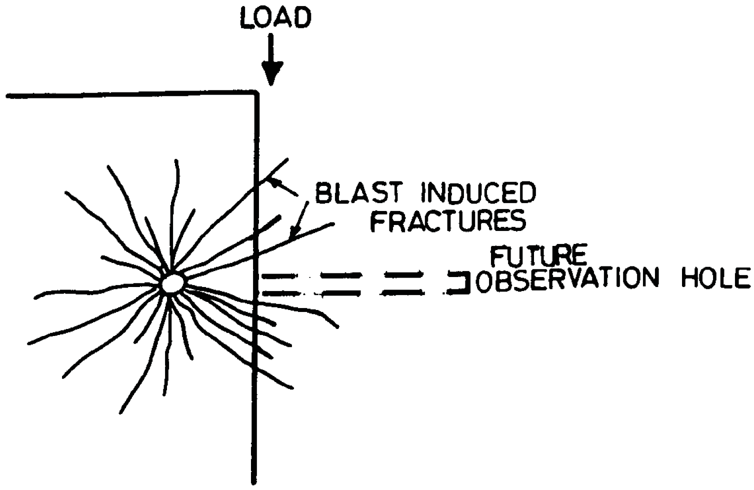

FIG. 22a

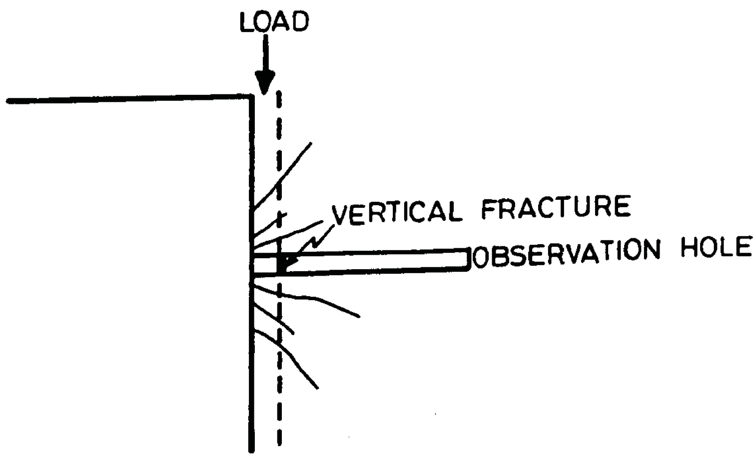

FIG. 22b

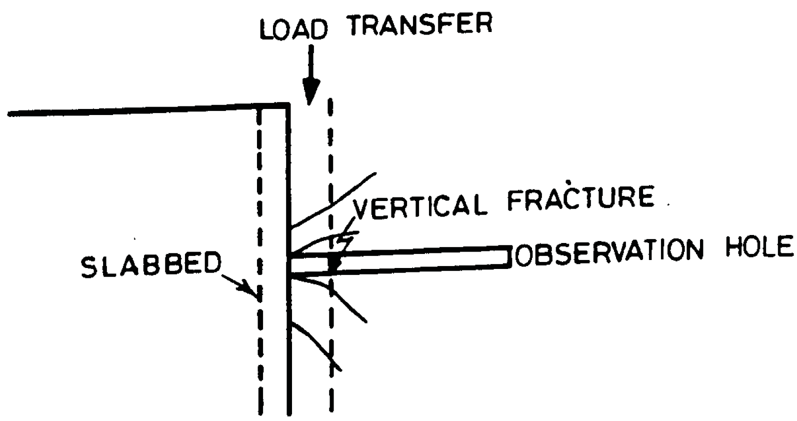

FIG. 22c

Figure 5.22 Mode of fracture formation and spalling in drill and blast sections.

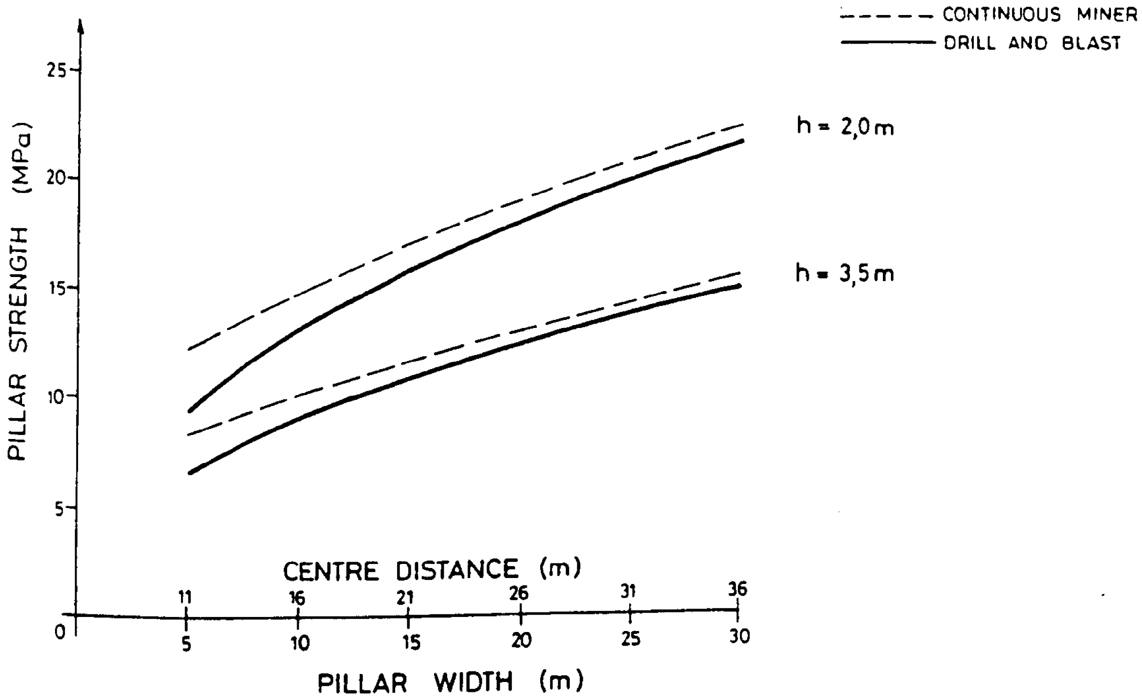

Figure 5.23 Pillar strengths for continuous miner and drill and blast formed pillars given designed bord and pillar width, centre distance constant.

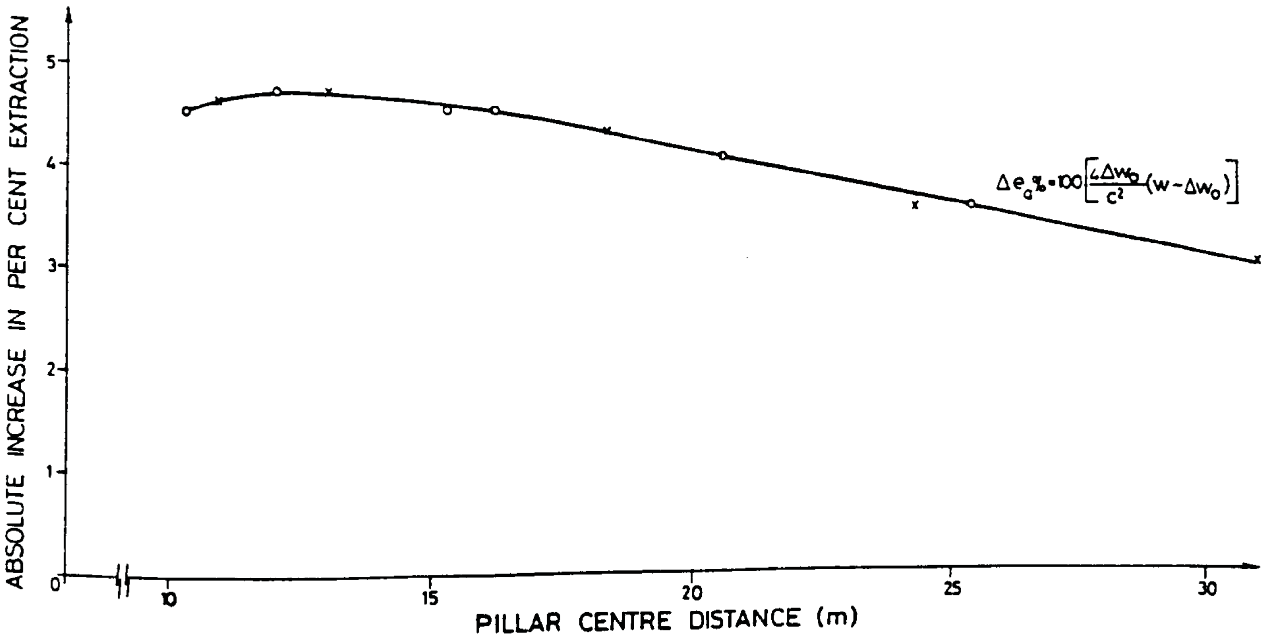

Figure 5.24 Absolute increase in percentage extraction for continuous miner over drill and blast extraction, pillar centre distance constant.

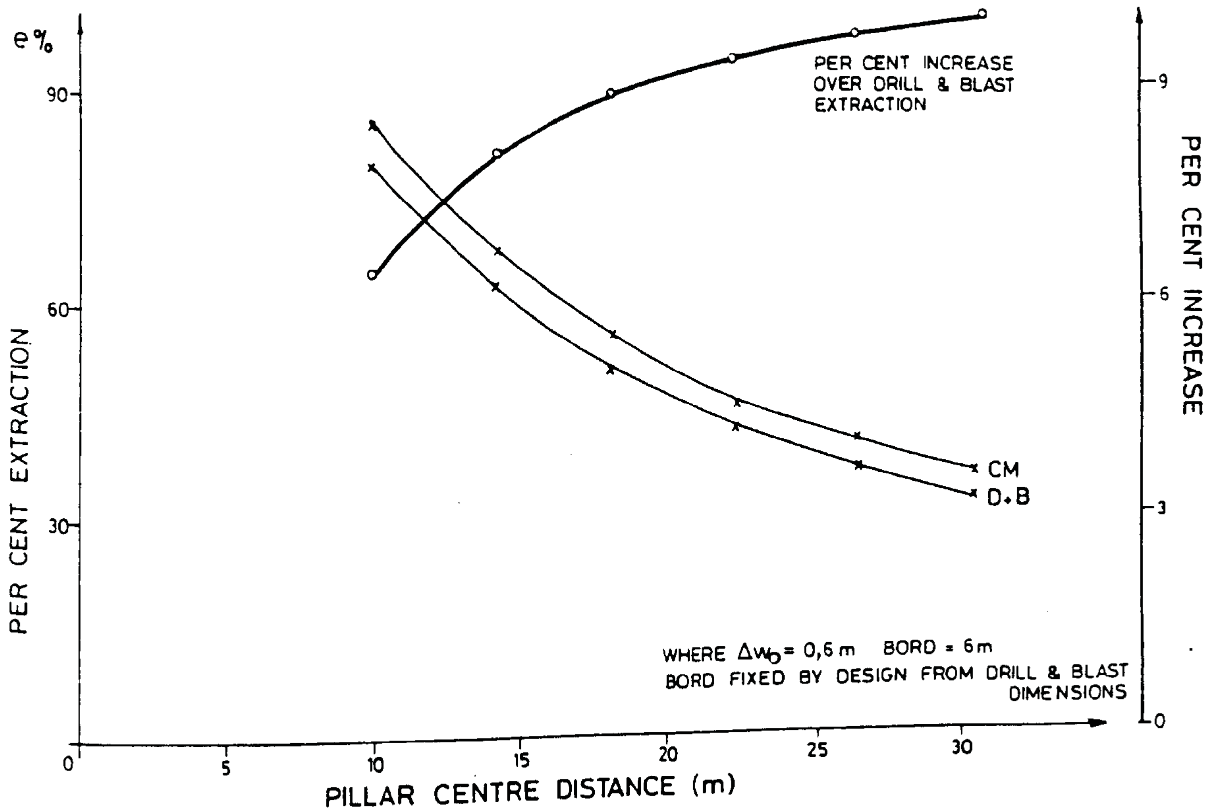

Figure 5.25 Comparison of percentage extraction of drill and blast and continuous miner designed pillars assuming a constant centre distance.