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TECHNICAL NOTE

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TITLE : THE INFLUENCE OF LEAD LENGTH ON THE FRACTURES ASSOCIATED WITH LEADING CORNERS AND SIDINGS

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ABSTRACT : Stopes on three reef horizons and at various depths were examined in the vicinity of inter-panel leads. The general geometry of fractures in the vicinity of inter-panel leads is outlined. The extent of fracturing parallel to the siding between leading and lagging panels was found generally to extend further into the lagging panel with increasing lead length. Curves fitted to the data seem to be asymptotic to a limiting fracture extent of about 15 to 20 m. More information is needed on the siding-parallel fracture extent associated with very long lead lengths. Other aspects requiring further investigation are outlined.

KEYWORDS : Fractures; Inter-panel leads/lags; Sidings; Siding-parallel fracture; Hangingwall-parallel fracture

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THE INFLUENCE OF LEAD LENGTH ON THE FRACTURES ASSOCIATED WITH
LEADING CORNERS AND SIDINGS

The fracturing associated with leads and lags has been known to cause poor hangingwall conditions in both the leading and lagging panels adjacent to the sidings. This initial investigation was undertaken to investigate the extent of the siding-parallel fracturing in the lagging panel and its relationship with lead lengths. The incidence of siding-parallel fractures was recorded on three reefs at various mining depths.

1. SCOPE AND PURPOSE OF THE INVESTIGATION

Five fracture geometries have been recognized as being likely to influence hangingwall stability immediately up and down dip of the sidings between leading and lagging panels. These are (Figure 1):

- (A) hangingwall-parallel fractures formed over the leading corner of the stope. These are formed within the face-parallel slabs which were developed ahead of the leading face
- (B) the strike curvature and flattening of dip of face-parallel fractures formed ahead of and round the leading corner of the stope. Fractures formed some distance ahead of the face curve over several metres. Fractures formed close to the face curve over 1-2 m.
- (C) siding-parallel fractures formed up dip of the siding
- (D) face-parallel fractures formed ahead of the lagging face
- (E) fractures with strike curvature formed ahead of the lagging face in the corner at siding/lagging face intersection.

The initial fracture survey reported here was limited to the extent and frequency of the siding-parallel fractures and their interaction with the face-parallel fractures formed ahead of the

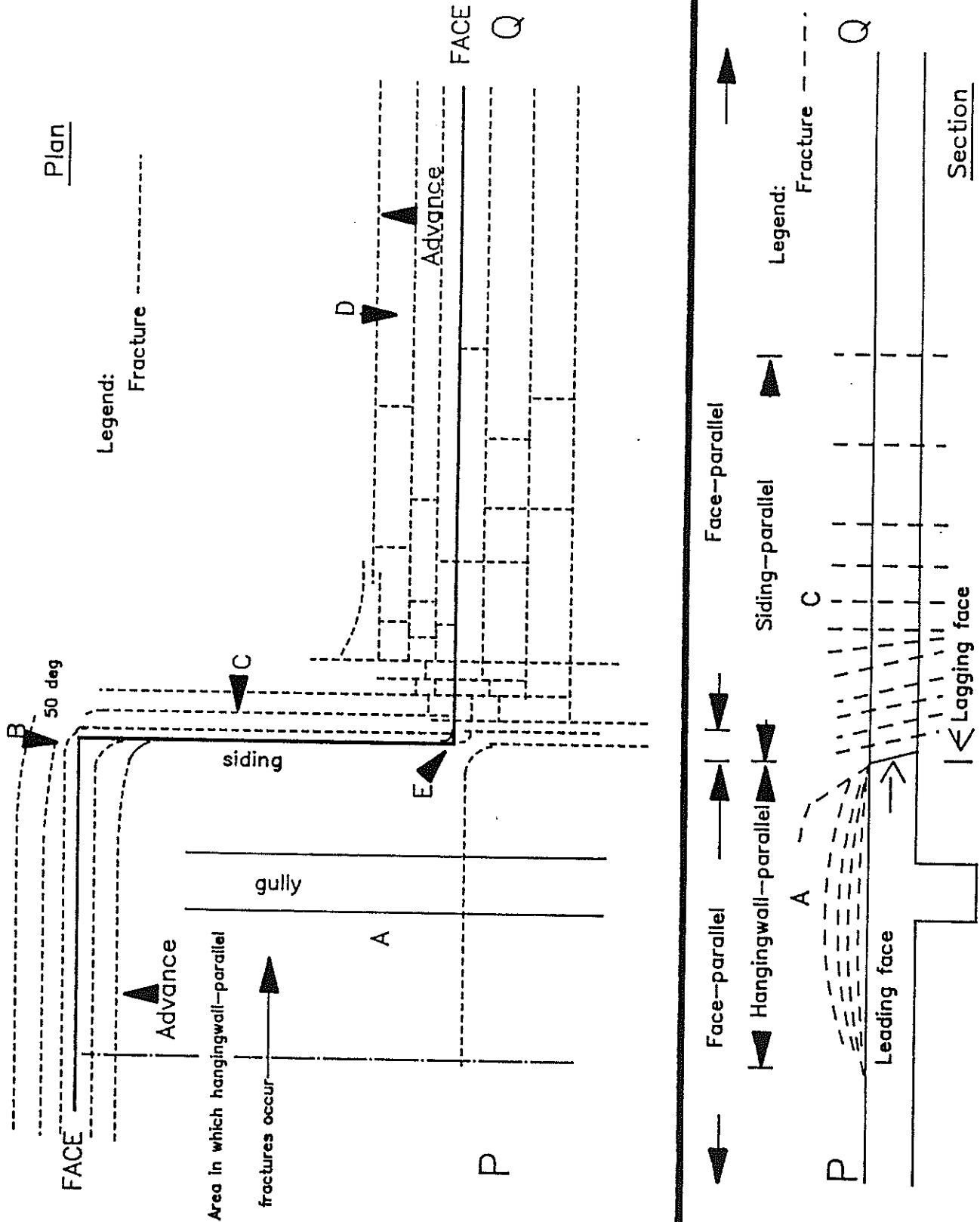


Figure 1. Fractures associated with inter-panel leads.

lagging panel. Contrasts were sought which might be related to mining depths at various lead lengths and to differences between the country rock lithologies associated with different reefs.

In the course of the survey 59 panels on 6 mines and 3 reefs were examined. The mining depths ranged between 1 800 m and 3 200 m.

1.1 The Framework for the Investigation

A preliminary reconnaissance survey of several panels was undertaken on Western Deep Levels with the objective of clarifying the framework that would provide the basis for the investigation. The end of the fracture zone was taken as being where the fracture spacing exceeded 1 m.

The following observations are pertinent to the underlying aim of this study, namely the influence of fracturing around leads, sidings and lags on hangingwall stability in those stope areas in which such fractures occur.

- (a) Two categories of siding-parallel fractures could be distinguished (Figure 1) namely
 - (i) those that preceded the formation of face-parallel fractures ahead of the lagging face and displayed considerable lateral continuity and
 - (ii) those that were formed subsequently to the first face-parallel fractures and which, as a result, were truncated laterally against these face-parallel fractures.
- (b) Siding-parallel fractures, if very closely spaced, can almost completely preclude the formation of face-parallel fractures in a narrow zone adjacent to the siding in the lagging panel (Figure 1).
- (c) A zone of siding-parallel fractures which occurs closest to the siding may dip towards the lagging panel. This zone extends for 1 - 2 m into the lagging panel. Further

from the siding the dip of the fractures changes abruptly to an inclination nearly perpendicular to the stope plane. How often and under what circumstances this phenomenon occurs is not yet known.

- (d) Fractures formed in the corner between the siding and the lagging face, and which curve from a siding-parallel to a face-parallel orientation, occur only occasionally.

1.1 Fracture geometries associated with leading and lagging stope panels

The succession of coexisting fracture geometries which are likely to be encountered along a linear, face-parallel traverse from the leading panel into the lagging panel (along P-Q in Figure 1) is listed below. It is clear that the fractures encountered along such a traverse reflect:

- (a) the influence of the advancing leading panel face
- (b) the influence of the corner between the leading panel and the siding
- (c) the influence of the siding, on which is subsequently superimposed the influence of the lagging face and
- (d) which superimposes itself on the lagging face effects and
- (e) the fractures which reflect only the influence of the lagging face.

The succession of fractures is:

- (i) face-parallel fractures
- (ii) face-parallel + hangingwall-parallel fractures

- (iii) curved, moderately inclined, corner fractures (concave towards stope)
- (iv) siding-parallel fractures dipping into lagging face + (rare) curved, steeply inclined corner fractures (convex towards stope)
- (v) steep, laterally continuous, closely spaced, siding-parallel fractures
- (vi) steep, laterally continuous, more widely spaced, siding-parallel fractures + laterally discontinuous face-parallel fractures, which truncate against siding-parallel fractures
- (vii) face-parallel fractures + laterally discontinuous, siding-parallel fractures, truncating against face-parallel fractures
- (viii) face-parallel fractures.

2.1 Extent of Siding-Parallel Fractures in Lagging Panel

The distance to which siding-parallel fractures extend up the lagging panel from the siding/lagging panel corner is plotted against the lead length for the various geological and mining settings in Figures 2 - 8. The siding parallel fractures considered are those which had good lateral continuity. The siding-parallel fractures which were truncated laterally by face-parallel fractures, were recorded on only a few occasions and are not depicted on these graphs.

For all the reefs examined, although there was a moderate scatter of data, it was apparent that the siding-parallel fractures occurred progressively further up the lagging panel as the length of the interpanel lead increased. It had been postulated that the distance up the lagging panel, to which the siding-parallel fractures would occur, would approach some maximum at a certain lead length. It was

SIDING-PARALLEL FRACTURE EXTENT

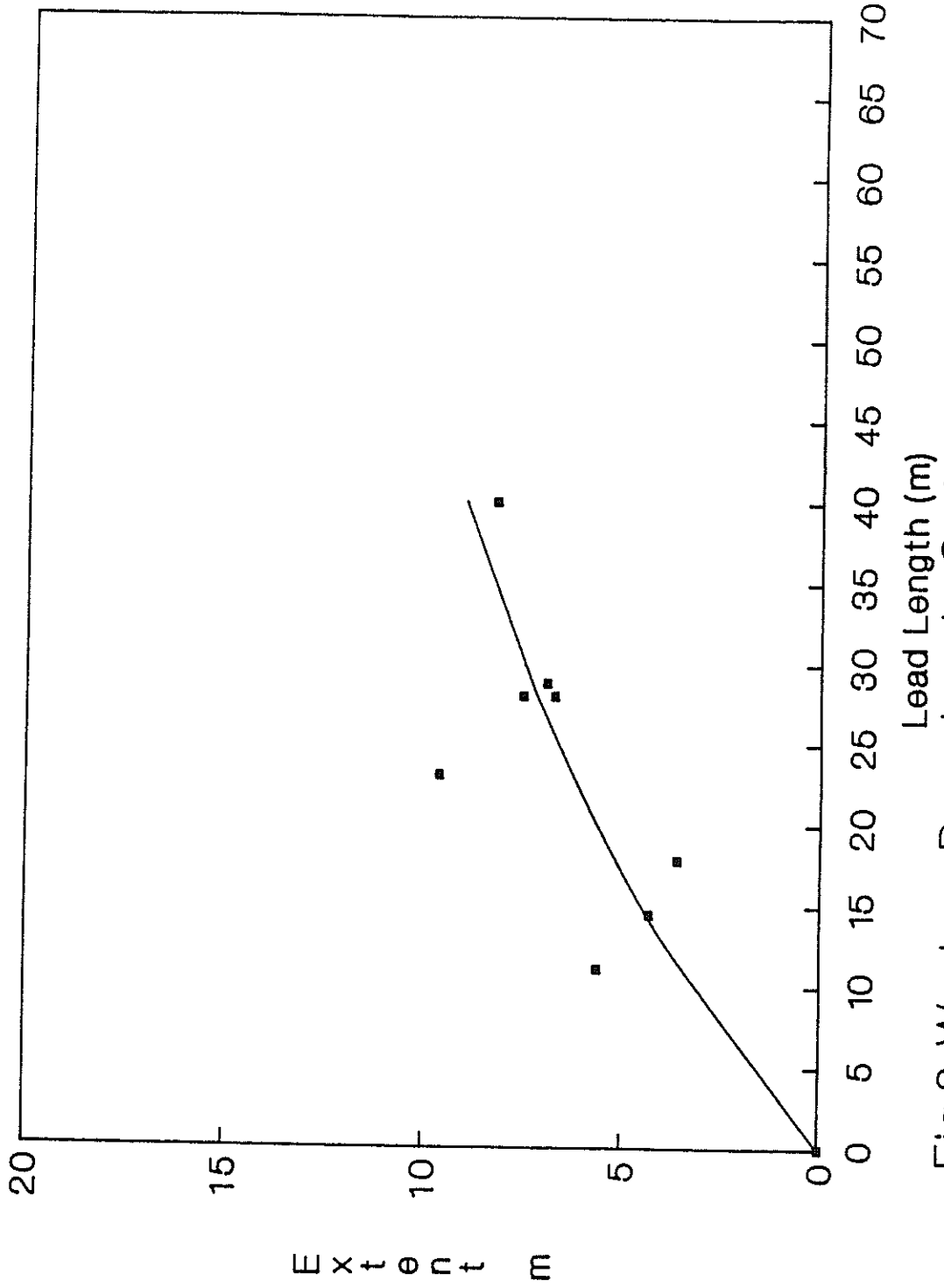


Fig.2 Western Deep Levels Carbon Leader Reef

SIDING-PARALLEL FRACTURE EXTENT

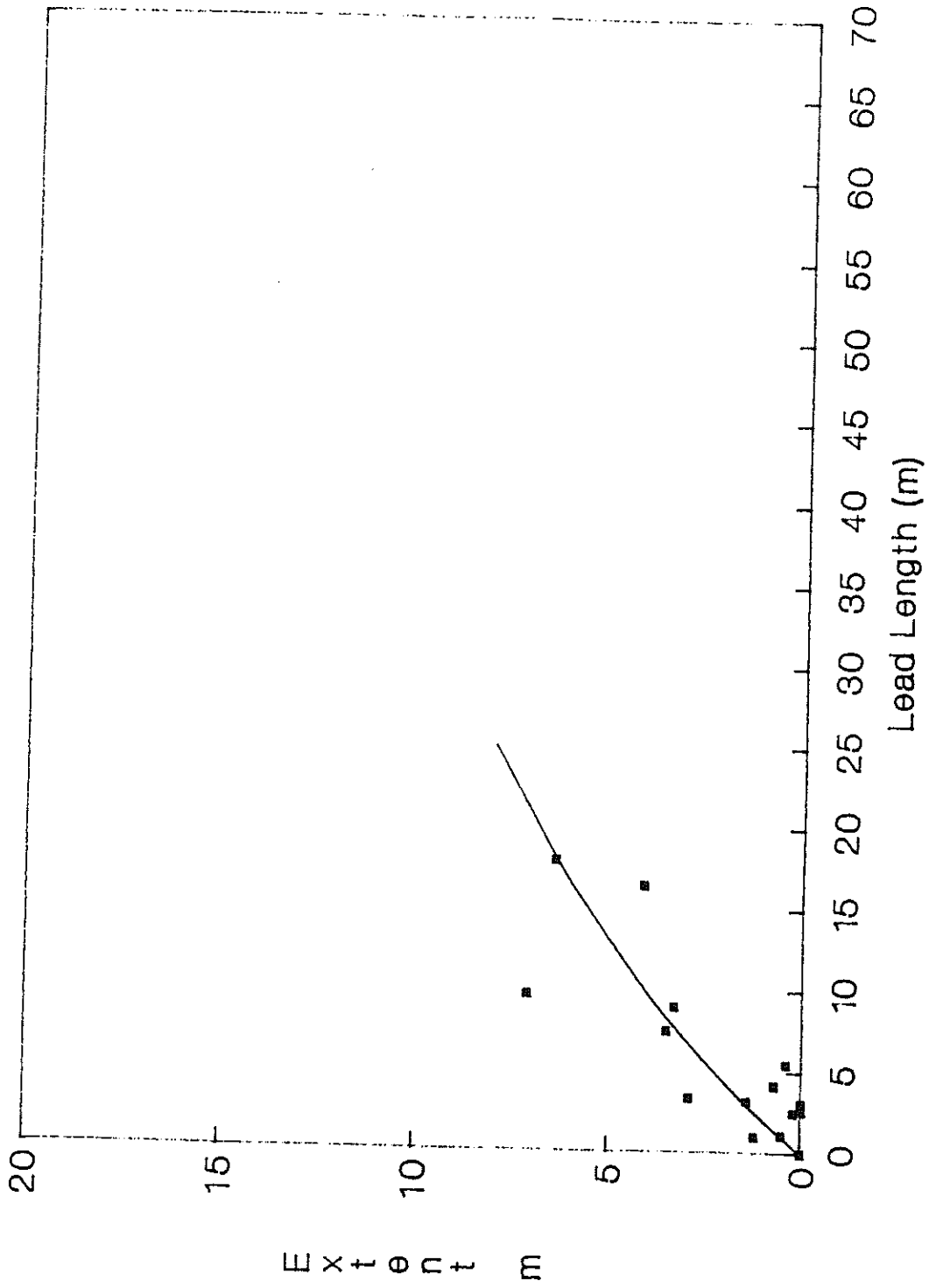


Fig.3 Doornfontein Carbon Leader Reef (>2200m)

SIDING-PARALLEL FRACTURE EXTENT

- Doornfontein — Doornfontein * Western Deeps
- Western Deeps - - - Composite

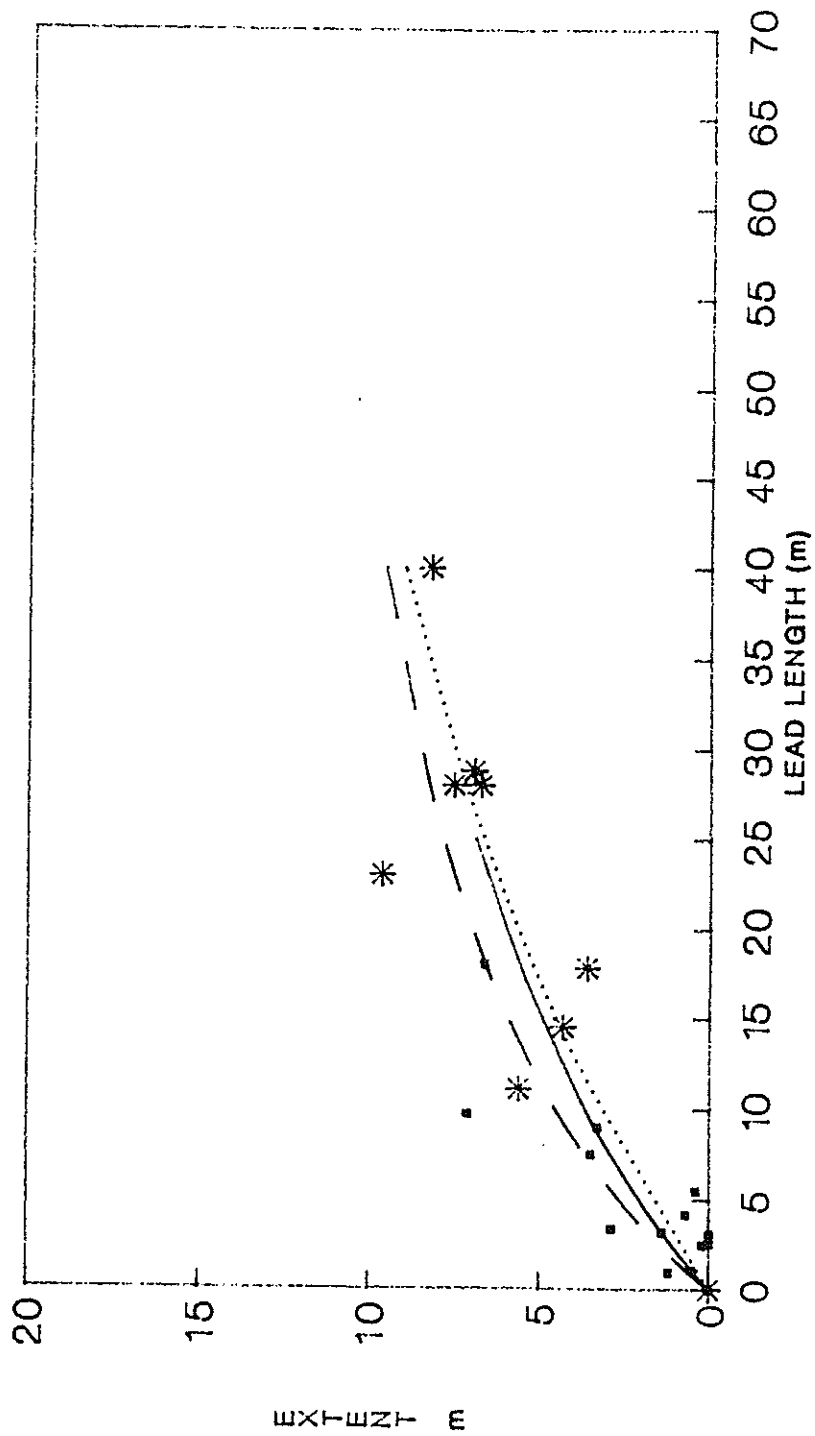


Fig.4 W.D.Levels and Doornfontein Carbon Leader

SIDING-PARALLEL FRACTURE EXTENT

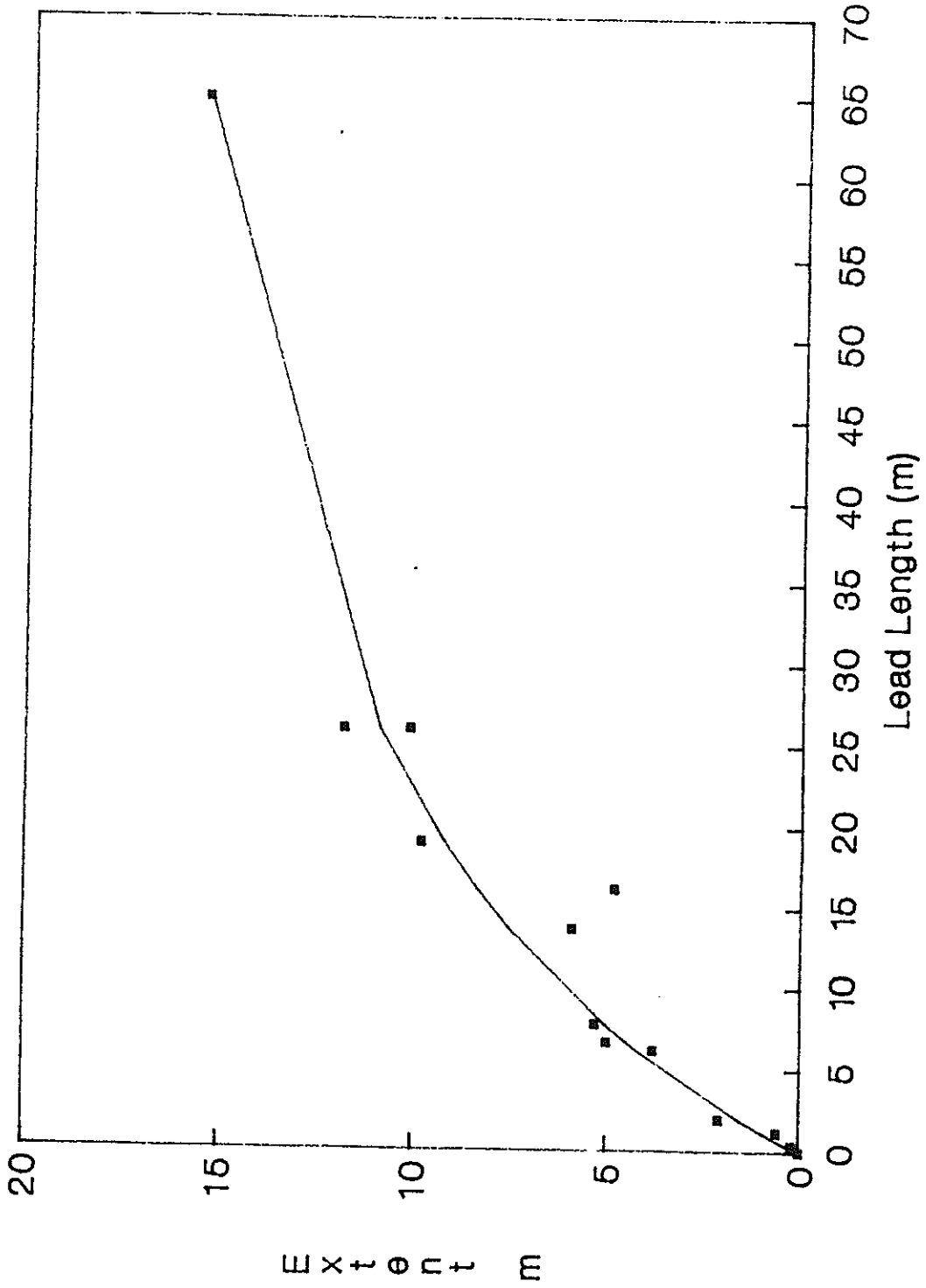


Fig.5 Haartebeesfontein and Buffelsfontein Vaal Reef

SIDING-PARALLEL FRACTURE EXTENT

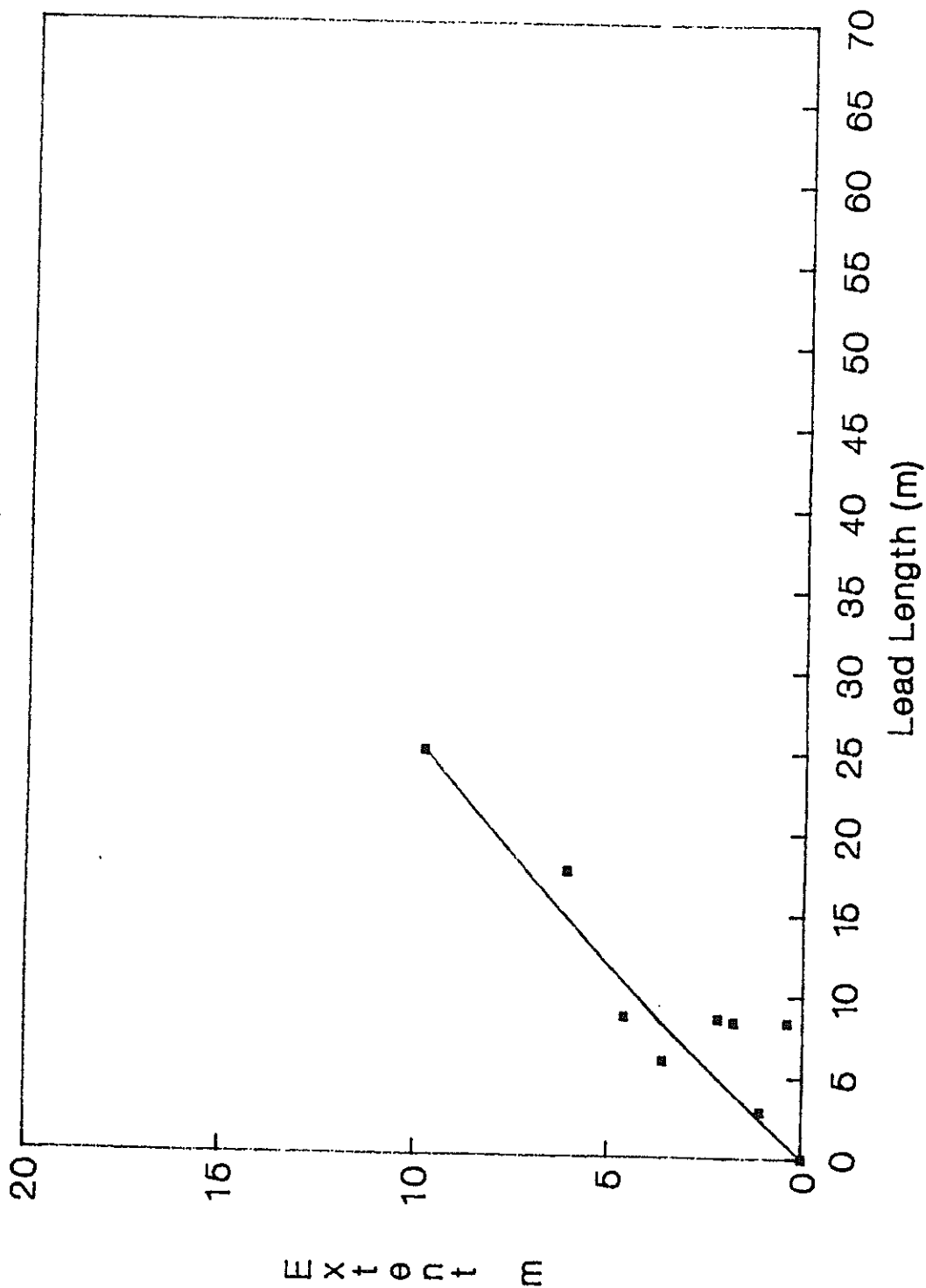


Fig.6 Pres Steyn Basal Reef (>2200m)

SIDING-PARALLEL FRACTURE EXTENT

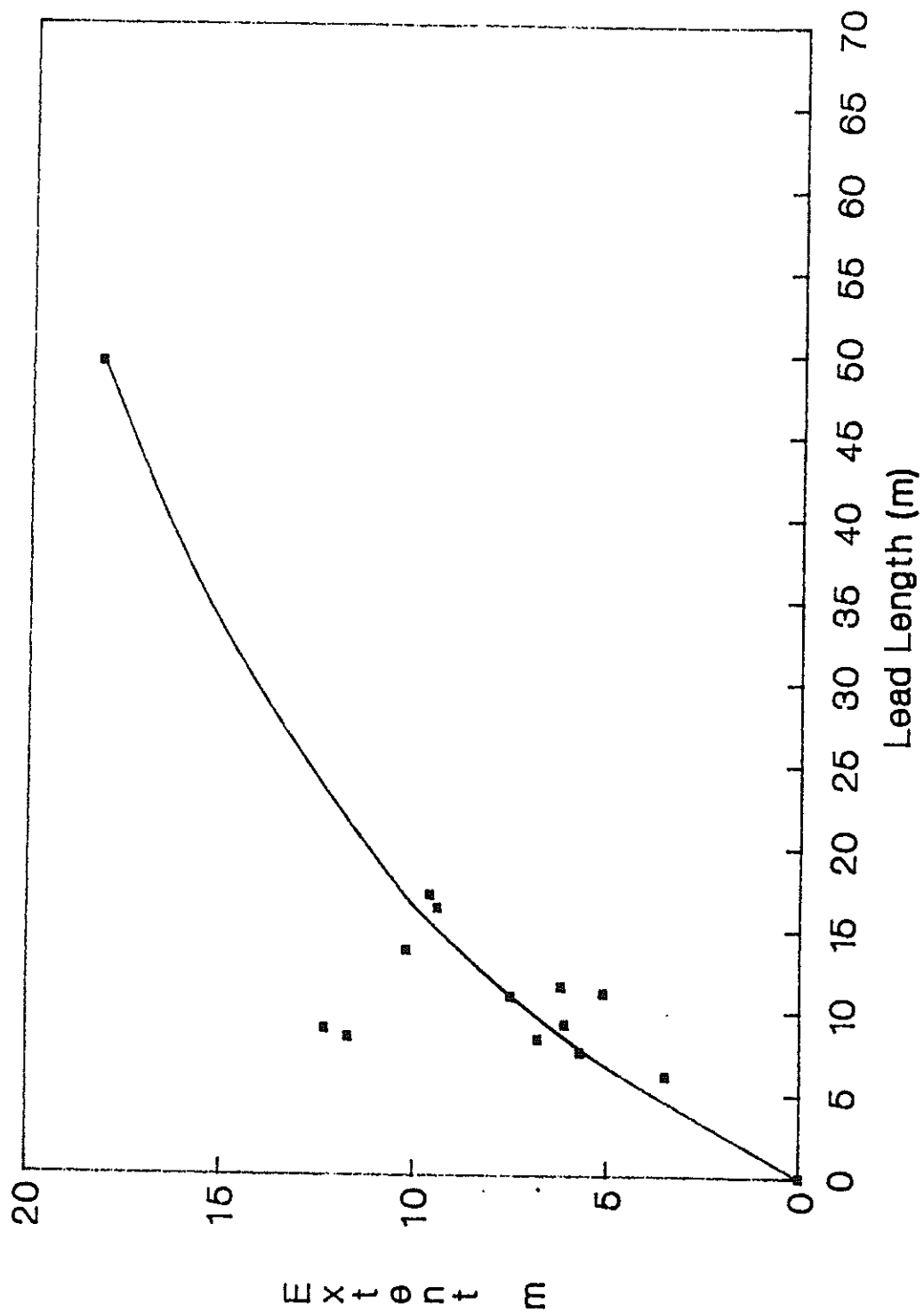


Figure 7. Harmony Basal Reef.

Siding-parallel fracture (Composite)

- WDL+Doorn △ Hartle+Buffel † Pres.Steyn □ Harmony
- WDL+Doorn — Hartle+Buffel ····· Pres.Steyn — Harmony

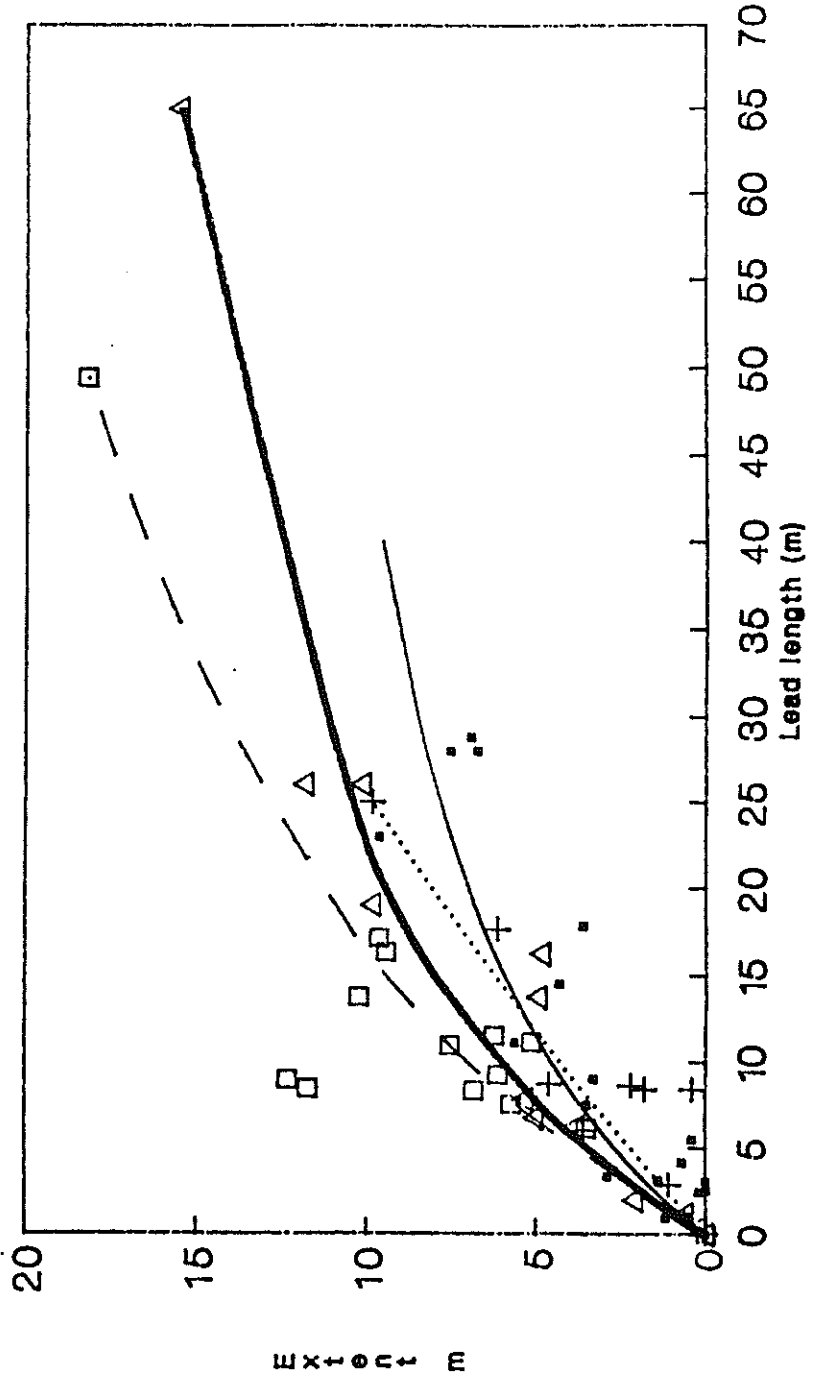


Figure 8 Carbon Leader, Vaal reef and Basal reef

expected that at larger lead lengths the extent of siding-parallel fractures would not increase significantly. The data tends to confirm this hypothesis.

Curves were fitted to the data populations using a function of the form

$$y = \frac{Ax}{b+x}$$

which is asymptotic to the line $y = A$.

These curves are plotted on Figures 2 - 8 together with the data points on which they are based. The curves are seen to inflect at some distance into the lagging panel. After this they exhibit a much slower increase in distance into the lagging panel with increasing lead length.

Figure 4 is a plot of the data and curves for the Western Deep Levels and Doornfontein data together with a composite curve for these Carbon Leader mines. Comparison between the individual curves in Figure 4 suggests that they do not differ significantly despite a depth difference of about 1 000 m between the stopes examined. Both mines are operating with large longwalls in which large stope spans will have resulted in total closure. However because of the stabilizing pillars on WDL the energy release rates would be similar in the panels investigated on the two mines thus explaining the minimal difference in results.

As mentioned, the furthest siding-parallel fractures which are laterally truncated by face-parallel fractures were infrequently picked up. When observed, however, they were, with one exception, further into the lagging panel than the laterally continuous siding-parallel fractures in the same panel. More data is needed on this category of siding-parallel fracture for meaningful conclusions regarding their occurrence to be drawn.

2.2 Preliminary Analysis of the extent of Siding-Parallel Fracture

The data for the laterally continuous siding-parallel fractures indicates that these fractures occur between 0,5 m and 1 m further into the lagging panel for every 1 m increase in the lead length up to a lead length of about 5 m. Between 5 and 15 m lead length the rate at which the distance into the lagging panel increased with increasing lead length, decreased markedly until, in the lead length range between 15 and 40 m, the rate was between 0,75 and 1,5 m per 10 m increase in lead length.

It must be emphasized that sparseness of data makes these last mentioned rates of change somewhat uncertain. (Only 4 of the 59 panels examined were associated with leads greater than 30 m and 10 panels were associated with leads greater than 20 m.)

2.2.1 Discussion of the observations on siding-parallel fracture extent

It is evident from Figure 8 that the extent of siding-parallel fracturing is different in the four different geological settings summarized by the regression curves. At 30 m lead length the extent of fracturing ranges between 7 m on the Carbon Leader, through 10 m for the Vaal Reef and Basal Reef on President Steyn, to 13 m for the Basal Reef on Harmony.

The source of this difference seems likely to be a combination of difference in ERR and the thickness of the hangingwall beds which ranges from about 0,5 m on Harmony through 0,8 - 1 m on President Steyn and on the Vaal Reef to about 1,5 - 2 m on Western Deep Levels where all the longer lead length data for the Carbon Leader were collected. It has been shown that geological joint spacing (Ladeira and Price, 1981), and hence the susceptibility to fracturing of strata, is approximately proportional to bed thickness up to a bed thickness of 1-2 m. Since the extent of siding-parallel fracturing was measured to the point where siding-parallel fractures were 1 m or less apart, it would be expected that this cut off point would be reached furthest into the lagging panel for the thinnest hangingwall bedding and vice versa.

The data for Doornfontein and Western Deep Levels appearing to belong to the same data population might also be attributable to the presence of bedding planes within the immediate hangingwall of the stopes on Doornfontein and to their general absence on Western Deep Levels.

To confirm this postulate regarding the influence of bedding thickness on the extent of siding-parallel fracturing several other geological settings will have to be studied.

2.3 The Extent of Exclusive Siding-Parallel Fracturing

The term exclusive siding-parallel fracturing is used to denote the zones adjacent to the sidings in which the prior formation of siding-parallel fracturing effectively stopped the formation of face-parallel fracturing ahead of the lagging face. Examination of Figures 9 - 11 reveals that the extent, or even existence, of such exclusive siding-parallel fracture zones bears no apparent relationship to the length of the interpanel lead. The most that can be deduced is that, for the Carbon Leader, Vaal and Basal reefs (on President Steyn), exclusive siding-parallel fracture zones occur in 30 to 50 per cent of cases and may extend as far as 6 m into the lagging panel. On Harmony no exclusive siding-parallel fracture zones were observed.

3. DISCUSSION OF THE INITIAL FINDINGS

The general postulate that the extent of the siding-parallel fracturing in lagging panels would be dependent on the lead length between panels has been confirmed. The initial indications are that the rate at which the siding-parallel fractures extend into the lagging panel diminishes appreciably between lead lengths of 5 to 15 m but, contrary to the initial postulate, thereafter continues to increase at a decreasing rate. Intuitively one would postulate that this rate too should decrease further to zero. The paucity of data for long leads renders the interpolation produced by the log regression technique somewhat dubious for lead lengths longer than 30 m. The scatter of data is such that the extent of fracturing could

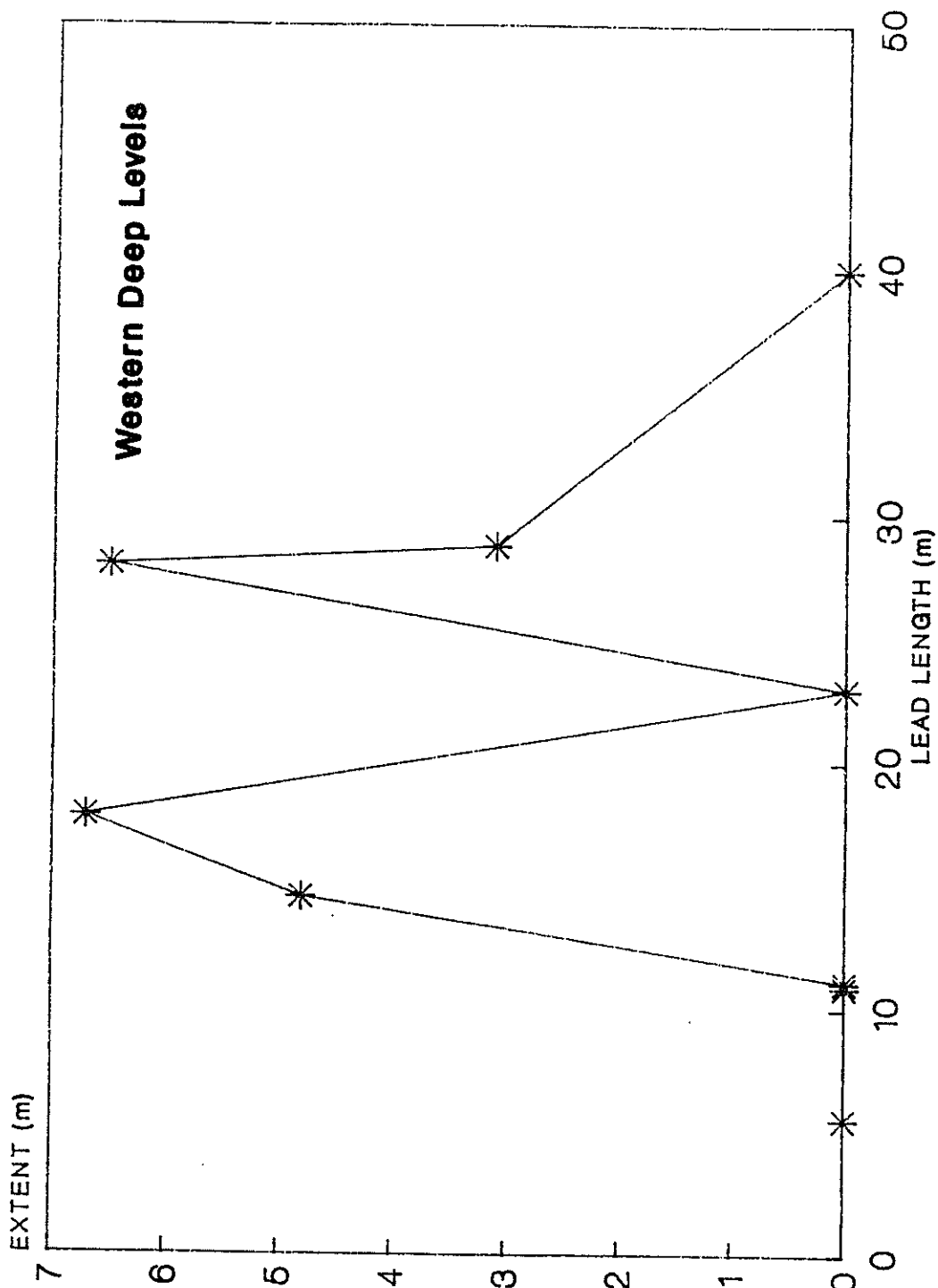


Figure 9 Exclusive sidng-parallel fracture, Carbon Leader

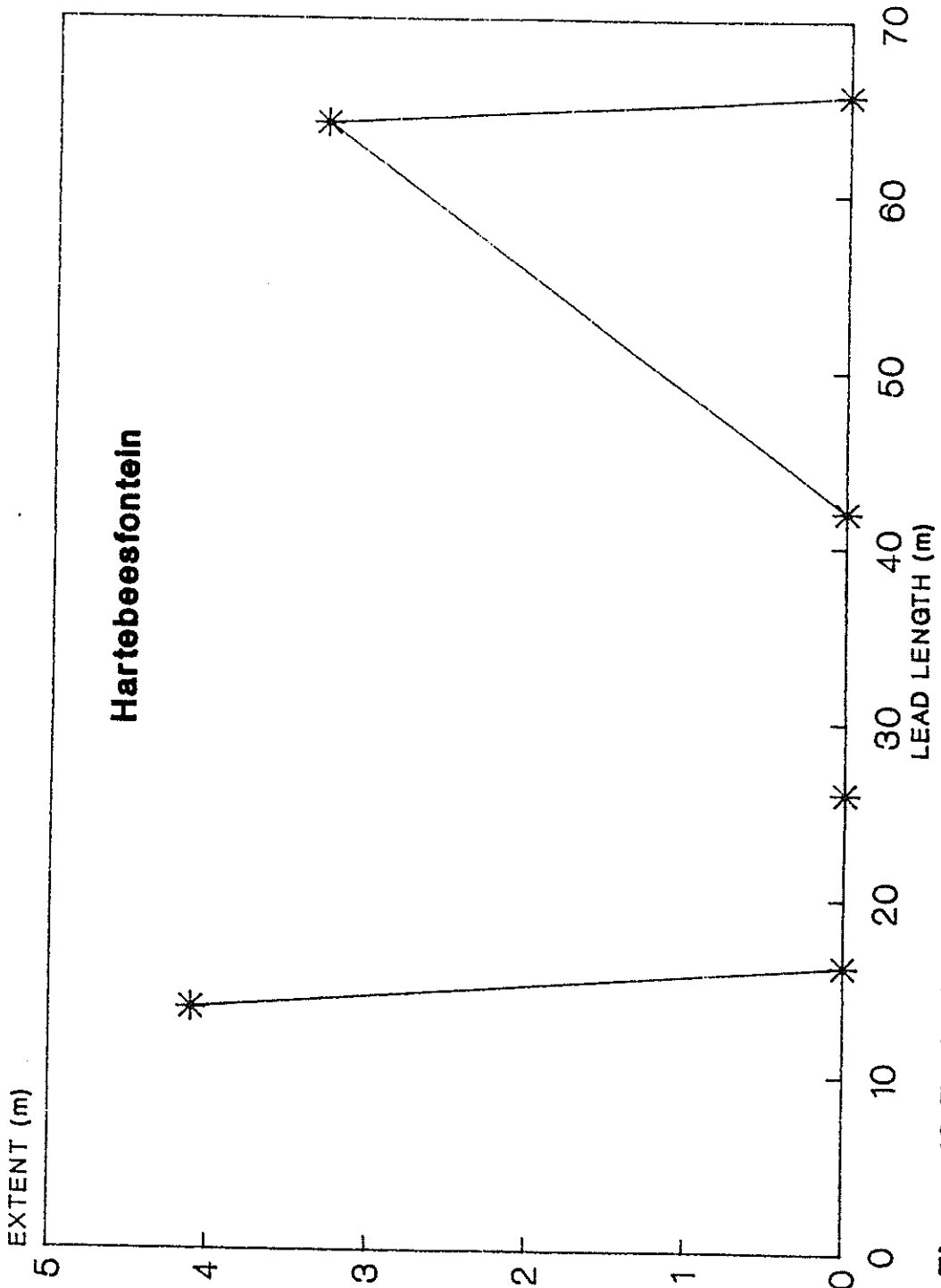


Figure 10 Exclusive sliding-parallel fractures, Vaal reef

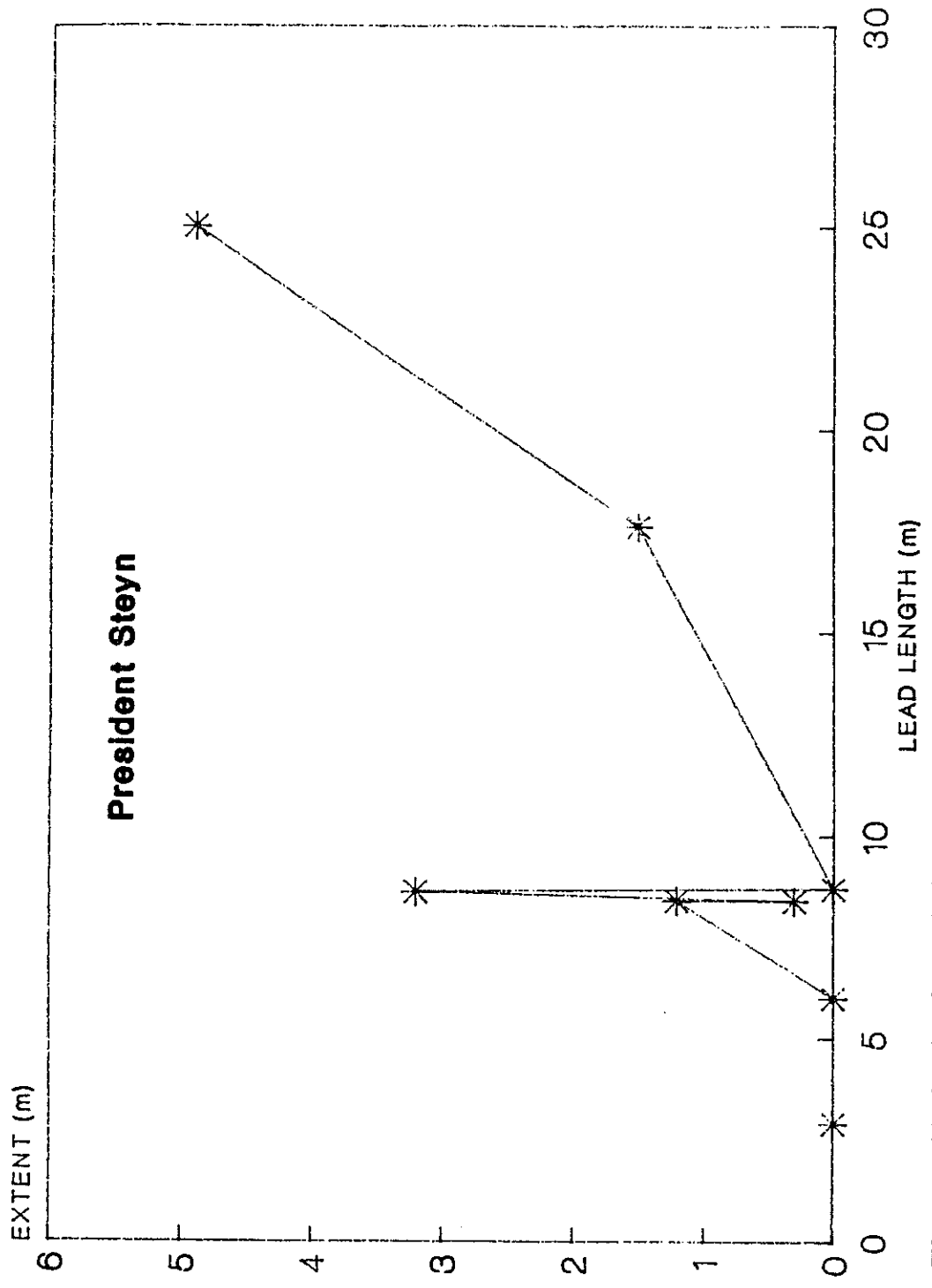


Figure 11 Exclusive sliding-parallel fractures, Basal reef

be expected to vary by two or three metres on either side of the regressing curves.

The incidence and extent of exclusive siding-parallel fracture zones seems to be erratic and unrelated to lead length. No conclusions can be drawn regarding their presence, absence or extent into the lagging panel.

The few observations that were made, indicate that the laterally truncated siding-parallel fractures extend several metres further into the lagging panel. These laterally discontinuous siding-parallel fractures would be likely to impart a lesser instability to the hangingwall than the laterally continuous siding-parallel fractures. This zone of lesser instability might be subject to falls of ground after an initial fall in the zone destabilized by the laterally continuous siding-parallel fractures.

4. IMPLICATIONS FOR SUPPORT

Despite the fact that this report presents only preliminary data on the nature and extent of siding parallel fracturing, conclusions can be drawn which are of significance to the design of support for the lower portion of lagging panels.

It was found that cross-fracturing, comprising face-parallel and siding-parallel fractures, extends approximately 5 to 10 m up-dip of the siding into the lagging panels for situations where the interpanel lead is between 5 and 15 m respectively. The cross-fracturing results in blocky ground which is further complicated by oblique 'corner fractures' which dip at moderate angles. The hangingwall in this portion of the panel is thus unstable because of the fracturing and the many potential keyblocks. The instability of the gully area has long been recognized but the reasons for the instability and particularly the extent of the effected hangingwall has hither to not been clearly defined.

The function of support in the lower sections of panels is thus to hold in place the numerous, small blocks formed by the

fractures rather than to support long face parallel beams which predominate higher up the panel. The need for particularly good support coverage of the hangingwall above sidings is therefore clear.

In the middle of the panels long headboards oriented on strike are sufficient to provide the areal coverage necessary to support the face parallel beams which occur in this part of the panel. Closer to the gully siding, where blocky ground exists, a much more complete area coverage is required of the support, with cross-headboards being a minimum recommendation. A rectangular headboard or other linear type of areal support, oriented on dip to cross the siding parallel fractures does not appear to be sufficient to stabilize this blocky ground which, as shown here, extends down to the siding in 50 to 70 per cent of the stopes.

Another strategy to reduce the strata control problem resulting from siding parallel fractures is to minimize the length of leads. Lead lengths of less than 5 m would have a significant impact on the problem.

5. NECESSITY FOR FURTHER WORK

Further more detailed work is required to quantify more accurately a number of the conclusions discussed above. These are:

1. The siding-parallel fracture extent associated with long (> 30 m) leads needs to be further investigated. This could be of particular significance where stoping is to proceed along abutments from previous stoping.
2. The postulated influence of hangingwall bedding thickness, and possibly hangingwall lithology, on siding-parallel fracture formation extent and density needs further investigating.
3. The incidence and extent of laterally discontinuous siding-parallel fractures needs to be established. Special

care needs to be exercised not to misidentify blast fractures as such late-stage siding-parallel fracturing.

4. It will be required to establish where and why zones of exclusive siding-parallel fracturing occur.
5. The occurrence of inclined siding-parallel fractures and range of inclinations of such fractures adjacent to sidings needs to be ascertained. The presence of such inclined fractures could adversely influence hangingwall stability in that portion of the leading panel that the lagging panel face has just passed.
6. An assessment should be made of the incidence of falls of ground within the leading panel-lagging panel mutual influence zone outlined in section 1.1. The geometry of coexisting fractures will be likely to influence hangingwall stability.
7. The relevance to support designs of the fracture geometries outlined in section 1.1 and of the fracture distributions outlined above, needs to be carefully assessed. The occurrence and cause of falls of ground within the zone adjacent to leads needs to be ascertained within a range of mining environment.

6. REFERENCE

LADEIRA, F.L. and PRICE, N.J. Relationship between fracture spacing and bed thickness. J. Structural Geology. V 3, No 2. pp 179-183, 1981.