CHAPTER III

FALL OF GROUND STATISTICS IN TUNNELS AT IMPALA PLATINUM MINE

This analysis covers a five-year period from 1992 to 1996. In order to obtain meaningful results from the analysis, a sizable database of fall of ground accidents is required. To meet this requirement all the available reportable accident and lost time injury data were gathered and combined for the five-year period.

The following information was extracted from the accident reports for the analysis:

- Reef type
- Stope or Development.
- Depth below surface.
- Distance from face.
- Excavation size.
- Origin of the fall of ground. (Face, Hangingwall, Sidewall or Footwall.)
- Mechanism. (Buckling, Shear or Dead weight.)
- Size of fall of ground (Small, medium or large)
- Shape of fall (Block, dome, wedge or scaling).
- Dimension of fall of ground (Max. height, width, length, area, volume and weight.)
- Rock type.
- Proximity of major geological features (Faults, dykes, potholes and joint sets)
- Boundaries of the fall of ground (Joints, faults, dykes, chromitite layer).

The database was analysed looking at fall out heights. A 95% cumulative percentage cut-off limit was used, since it is accepted in the industry that the support system must be designed to prevent 95% of the falls of ground. This criterion will be adopted for analysis of the parameters pertaining to the fall of ground dimensions.

The database analysis was addressed using two approaches consisting of a quantitative statistical analysis then followed by an in depth detailed investigation of the accidents reports to extract any further useful information. The mean values calculated in the different quantitative statistical analyses are given in Table 3.1 with their respective 95% confidence limits.

The maximum dimensions were always measured with regards to the fall of ground size. For example a fall of ground with a wedge shape vertical cross-section, the maximum thickness is the measurement from the base to the apex of the wedge. The information was complied into a single database, which was later broken down into the four following databases for analysis:

⇒ ***Impala Mine***; the database containing all Impala Mine fall of ground accidents from 1992 to 1996.

⇒ ***Mine - Development***; the database containing all development fall of ground accidents on Impala Mine from 1992 to 1996.

⇒ ***Merensky - Development***; the database containing all the fall of ground accidents in Merensky Reef development from 1992 to 1996. This includes on and off reef development.

⇒ ***UG2 - Development***; the database containing all the fall of ground accidents in UG2 on and off reef development from 1992 to 1996.

TABLE 3.1 - Statistical Analysis of Falls of Ground accidents at Impala : '92-'96

Thickness – Dev (m)	
Mean	03148
Standard Error	0.058158175
Median	0.2
Mode	0.3
Standard Deviation	0.290790876
Sample Variance	0.084559333
Kurtosis	-0.12601531
Skewness	1.113088118
Range	0.88
Minimum	0.02
Maximum	0.9
Sum	7.87
Count	25
Largest (1)	0.9
Smallest (1)	0.02
Confidence Level (95%)	0.120032549

Areal Extent – Dev (m^2)	
Mean	2.0138
Standard Error	0.624213591
Median	0.98
Mode	0.06
Standard Deviation	3.121067953
Sample Variance	9.741065167
Kurtosis	7.843844574
Skewness	2.672870353
Range	13.49
Minimum	0.01
Maximum	13.5
Sum	50.345
Count	25
Largest (1)	13.5
Smallest (1)	0.01
Confidence Level (95%)	1.228313267

Length Dev (m)	
Mean	1.492
Standard Error	0.262419511
Median	1
Mode	0.3
Standard Deviation	1.312097557
Sample Variance	1.7216
Kurtosis	1.66300208
Skewness	1.23604191
Range	5.3
Minimum	0.1
Maximum	5.4
Sum	37.3
Count	25
Largest (1)	5.4
Smallest (1)	0.1
Confidence Level (95%)	0.541607141

Width – Dev (m)	
Mean	0.852
Standard Error	0.145644544
Median	0.7
Mode	0.2
Standard Deviation	0.728222722
Sample Variance	0.530308333
Kurtosis	2.463805994
Skewness	1.501189576
Range	2.9
Minimum	0.1
Maximum	3
Sum	21.3
Count	25
Largest (1)	3
Smallest (1)	0.1
Confidence Level (95%)	0.300595504

Weight Dev (Tons)	
Mean	3.108122
Standard Error	1.088052919
Median	0.873
Mode	#N/A
Standard Deviation	5.440264594
Sample Variance	29.59647885
Kurtosis	5.753835166
Skewness	2.3327567576
Range	22.31938
Minimum	0.00062
Maximum	22.32
Sum	77.70305
Count	25
Largest (1)	22.32
Smallest (1)	0.00062
Confidence Level (95%)	2.245630392

Volume – Dev (m^3)	
Mean	1.00262
Standard Error	0.350984812
Median	0.27
Mode	#N/A
Standard Deviation	1.754924062
Sample Variance	3.079758465
Kurtosis	5.753835166
Skewness	2.332767576
Range	7.1998
Minimum	0.0002
Maximum	7.2
Sum	25.0655
Count	25
Largest (1)	7.2
Smallest (1)	0.0002
Confidence Level (95%)	0.724396901

The development categories include on and off reef development. As the analysis broke the database down into reef horizons, stoping and development, a lack of data became a problem. The lack of data means low number of fatal accidents in development and no data available for ordinary falls of ground in development. Only the information describing the dimensions of the rockfalls for the period 1992 to 1996 will be analysed.

3.1 Results of the analysis of reportable and fatal fall of ground accidents from 1992 to 1996

The analysis was broken down into various categories for comparison purposes. The main purpose was to highlight the typical shape and size of falls of ground that need to be suitably supported in off-reef tunnel development. The analysis looks on a mine wide level, which will be focused on off-reef tunnel development, 34.5% of all reportable accidents occurred in development (i.e. off-reef tunnels, raises, re-raises, boxholes and travelway's) :

- 57.4% of the above occurred on the Merensky Reef Horizon.
- 41.6% of the above occurred on the UG2 Reef Horizon.
- the remaining 1% occurred during capital development projects (declines).

3.1.1 Size of falls of ground

The analysis consisted of 90 falls of ground representing 23.4% in off-reef tunnel development. This low number is due to the fall of ground dimensions not being recorded in every investigation report.

- Nearly all falls are discontinuity bounded, most commonly joints and chromitite layers
- Most falls of ground occur in the footwall of the Merensky Reef or the UG2 reef i.e. where the bulk of the mine tunnels are situated
- Falls confined to blocks, wedges or scaling are always discontinuity bounded.
- For length, width, height, weight, volume, areal and height a 95 cumulative percentage limit has been determined.

The following charts substantiate the above conclusions.

Figure 3.1 shows a cumulative percentage and histogram plot of the various thickness of reportable falls of ground accidents in mine development from 1992 to 1996. Thus 95% cumulative percentage of falls of ground thickness is 0.85m.

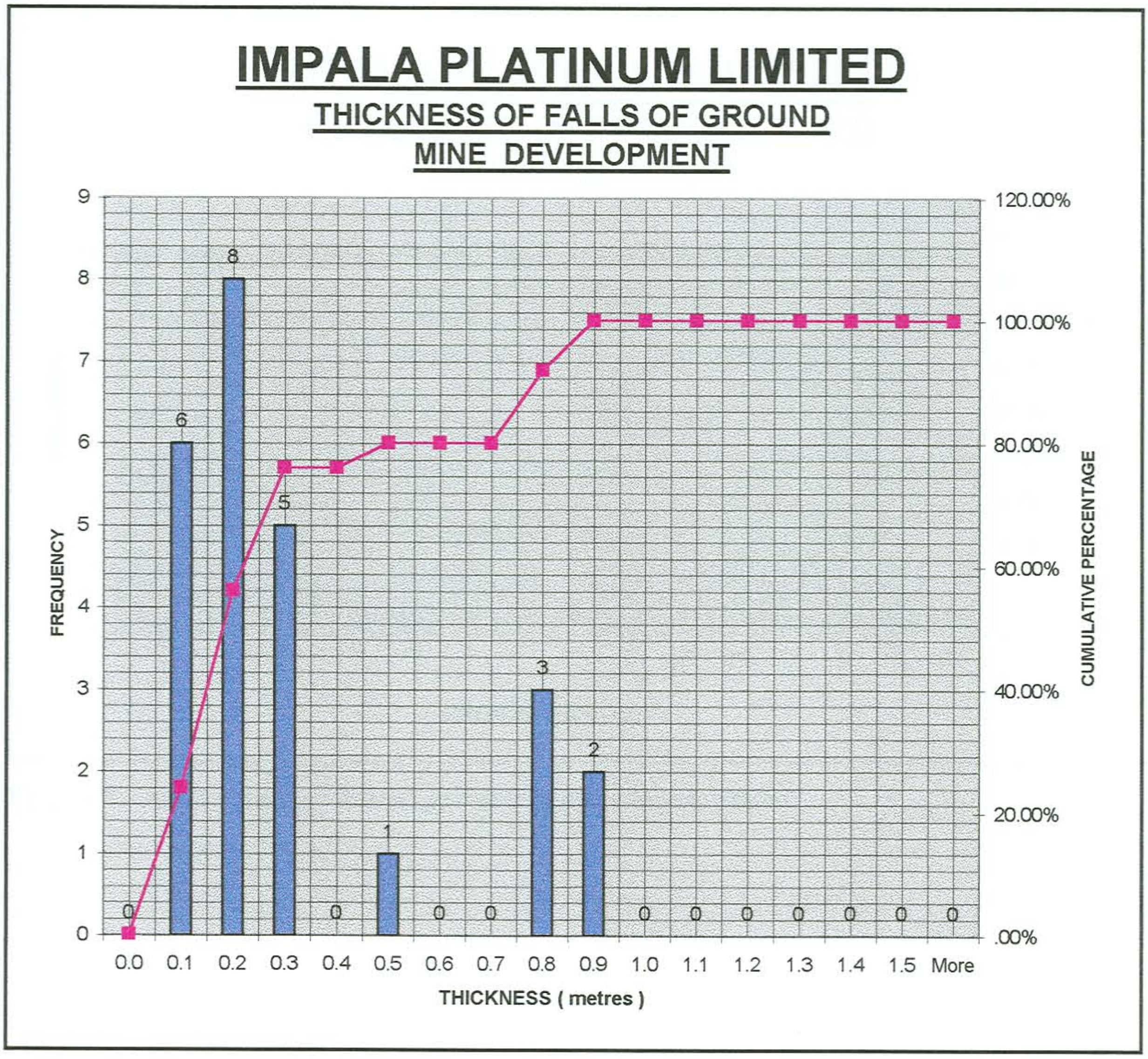

FIG. 3.1 - Fall out thickness in mine development

Figure 3.2 shows a cumulative percentage and histogram plot of the areal extent of reportable and fatal falls of ground accidents in mine development from 1992 to 1996. Thus the 95 cumulative percentage of falls of ground represent an areal extent of 9m².

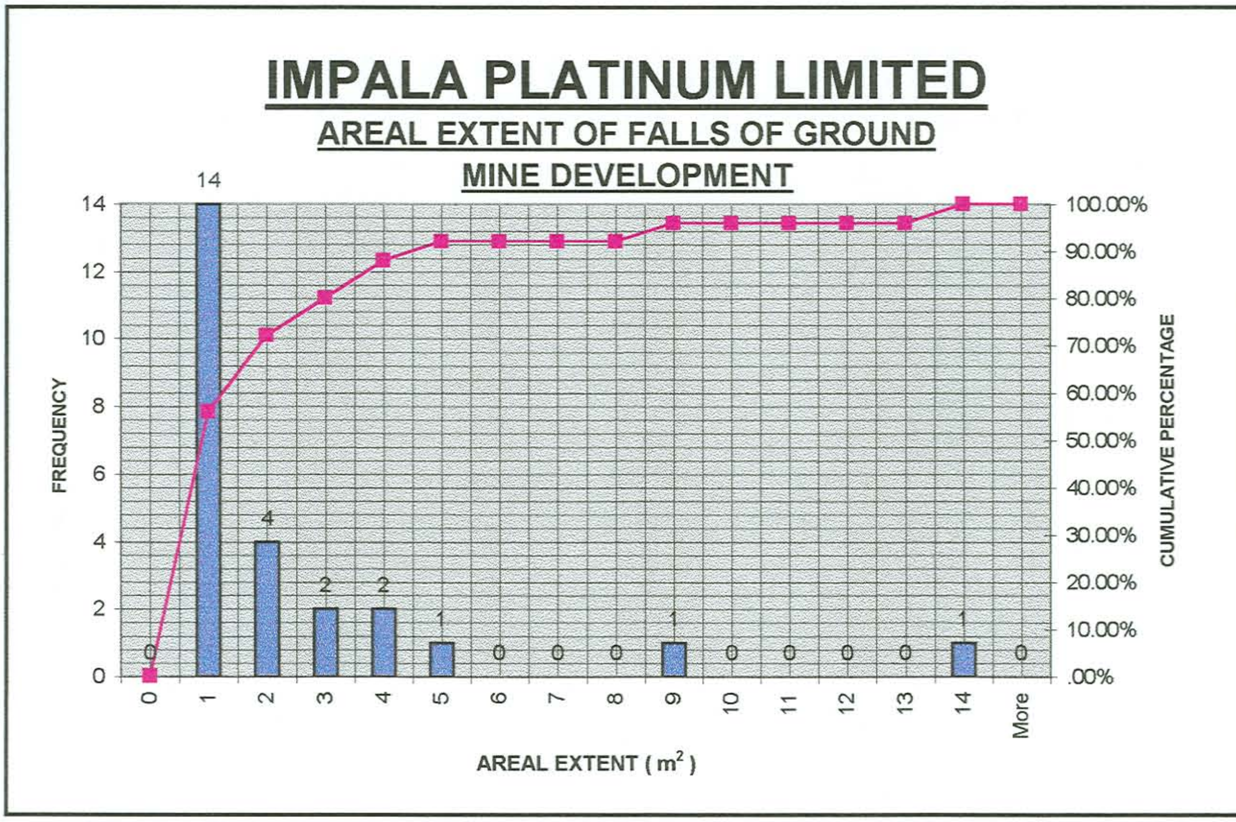

FIG. 3.2 - Areal extent of falls of ground in mine development

Figure 3.3 shows a cumulative percentage and histogram plot of the mass (kg's) of reportable falls of ground accidents in mine development from 1992 to 1996. Thus the 95 cumulative percentage of falls of ground represents a mass of 13 000 Kg.

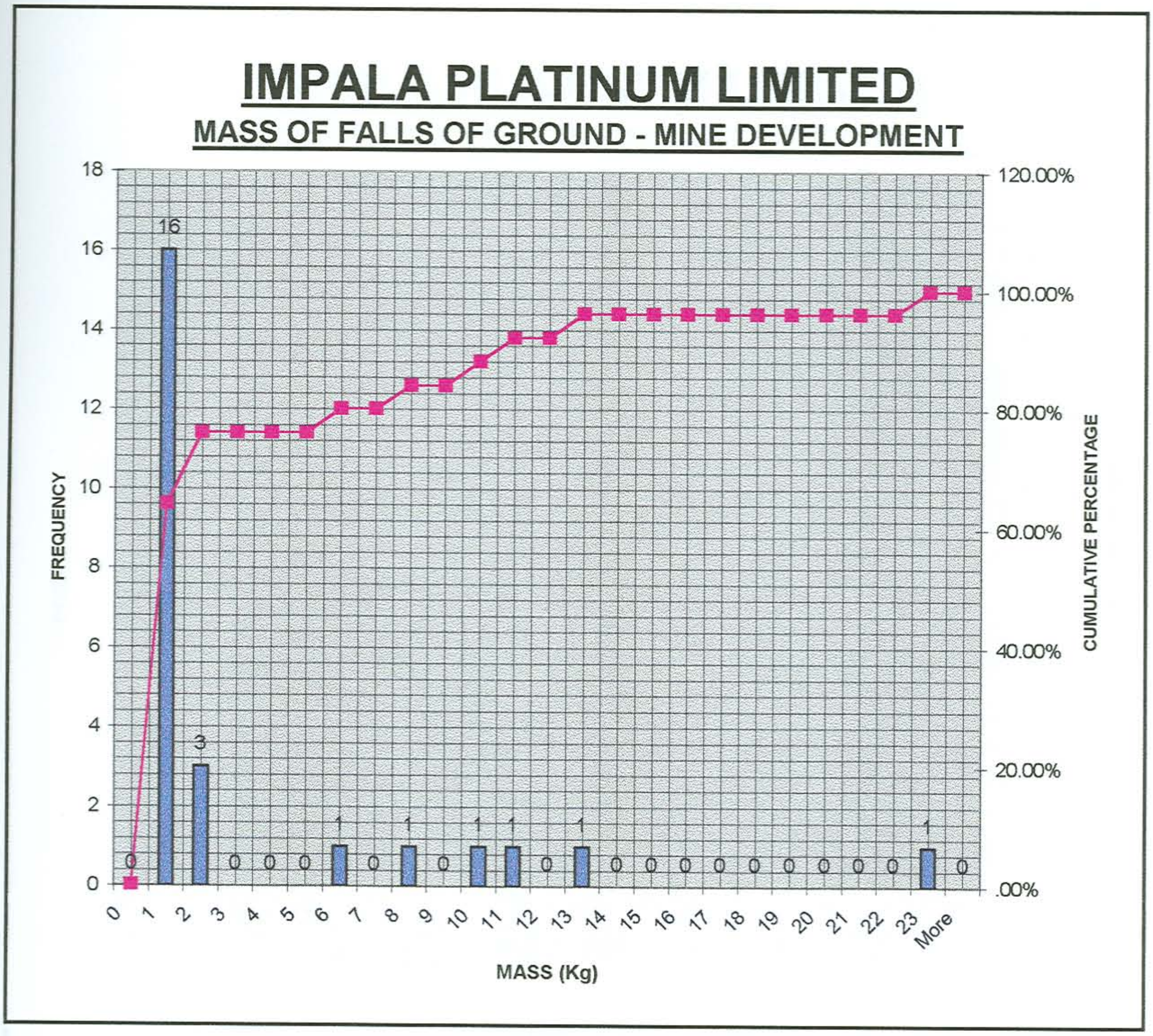

FIG. 3.3 – Mass of falls of ground in mine development

Figure 3.4 shows a cumulative percentage and histogram plot of the volume in m³ of reportable falls of ground accidents in mine development from 1992 to 1996. Thus the 95 cumulative percentage of falls of ground represents a volume of 5m³.

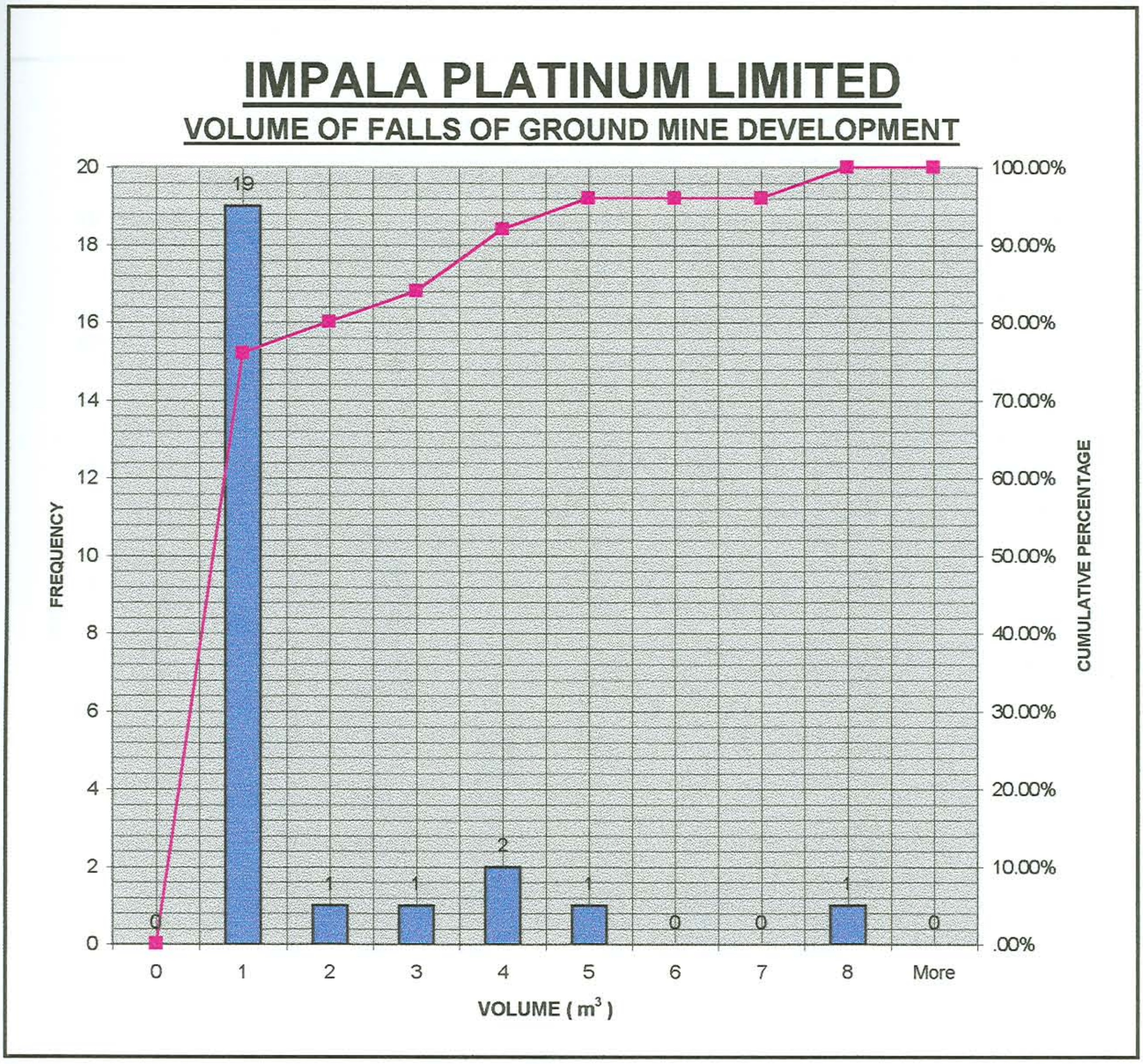

FIG. 3.4 - Volume of falls of ground in mine development

Figure 3.5 shows a cumulative percentage and histogram plot of the width (m) of reportable falls of ground accidents in mine development from 1992 to 1996. The width of falls of ground represents a measurement 90° to the long axis of a tunnel. Thus the 95 cumulative percentage of falls of ground represents a width of 2,5m.

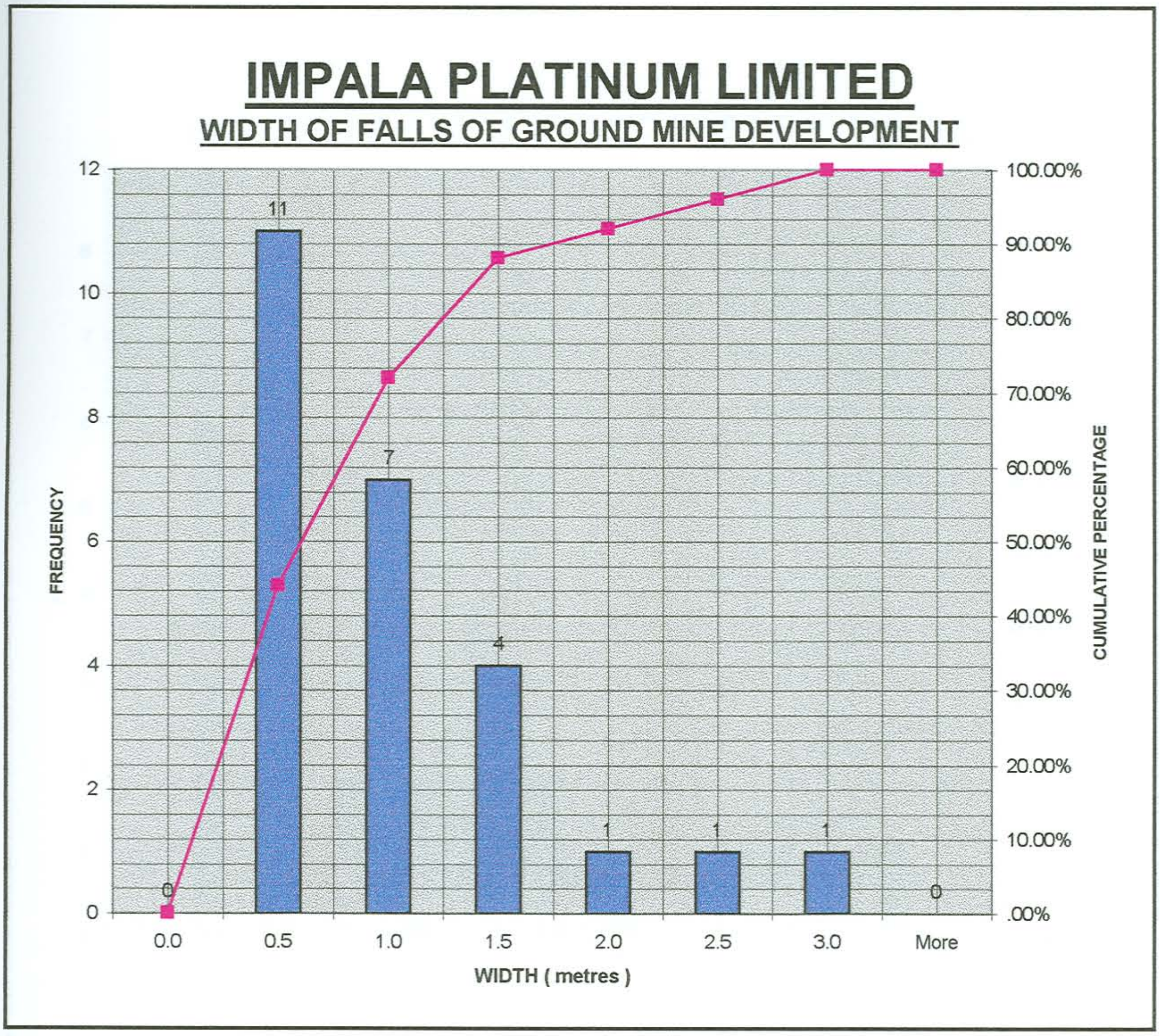

FIG. 3.5 - Width of falls of ground in mine development

Figure 3.6 shows a cumulative percentage and histogram plot of the length (m) of reportable and fatal falls of ground accidents in mine development from 1992 to 1996. The length of falls of ground represents a measurement parallel to the long axis of a tunnel. Thus the 95 cumulative percentage of falls of ground represents a length of 3,5m.

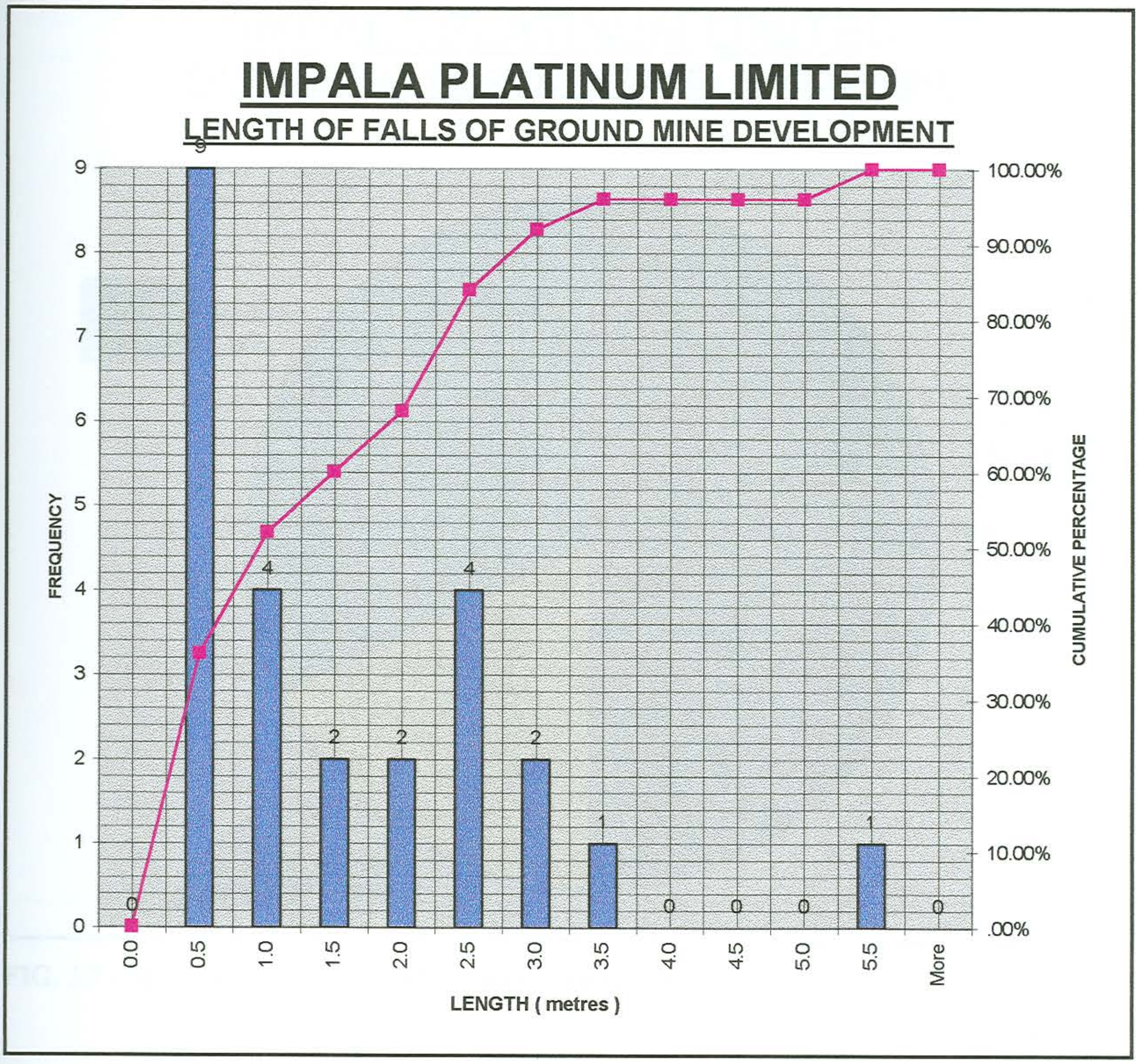

FIG. 3.6 - Length of falls of ground in mine development

Figure 3.7 shows a pie chart of the typical shapes of reportable and fatal fall of ground accidents in mine development from 1992 to 1996. Thus 50% of the falls of ground are represented by a block shape, 18% of the falls are represented by wedges and 32% by scaling.

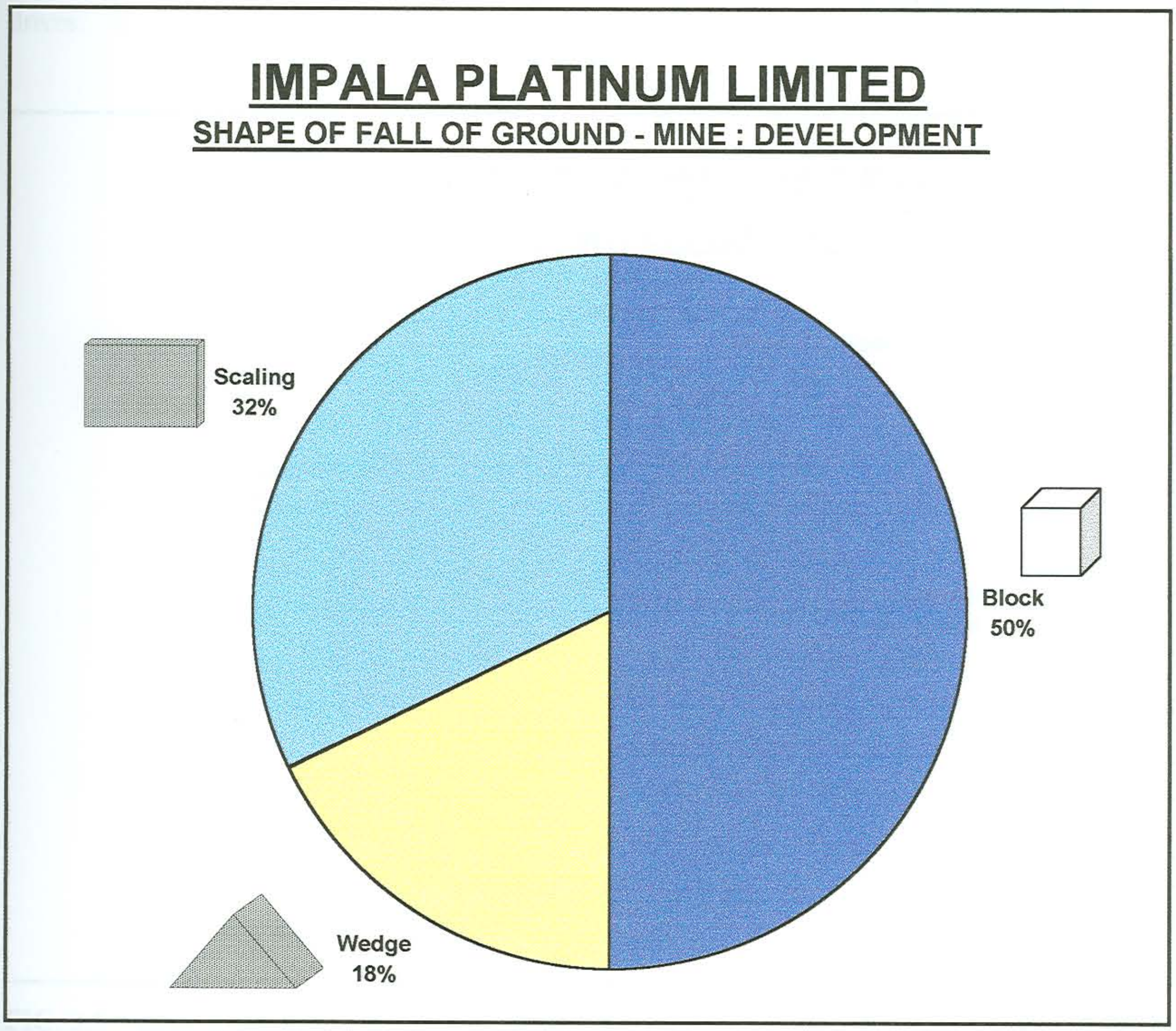

FIG. 3.7 - Shape of falls of ground in mine development

Figure 3.8 shows a pie chart of the typical rock type responsible for reportable falls of ground accidents in mine development from 1992 to 1996. Thus 34% of the falls of ground occurred from Merensky footwall in drives and 37% of the falls of ground occurred from UG2 footwall drives. The implication is that 71% of falls of ground in mine development originated in off-reef drives.

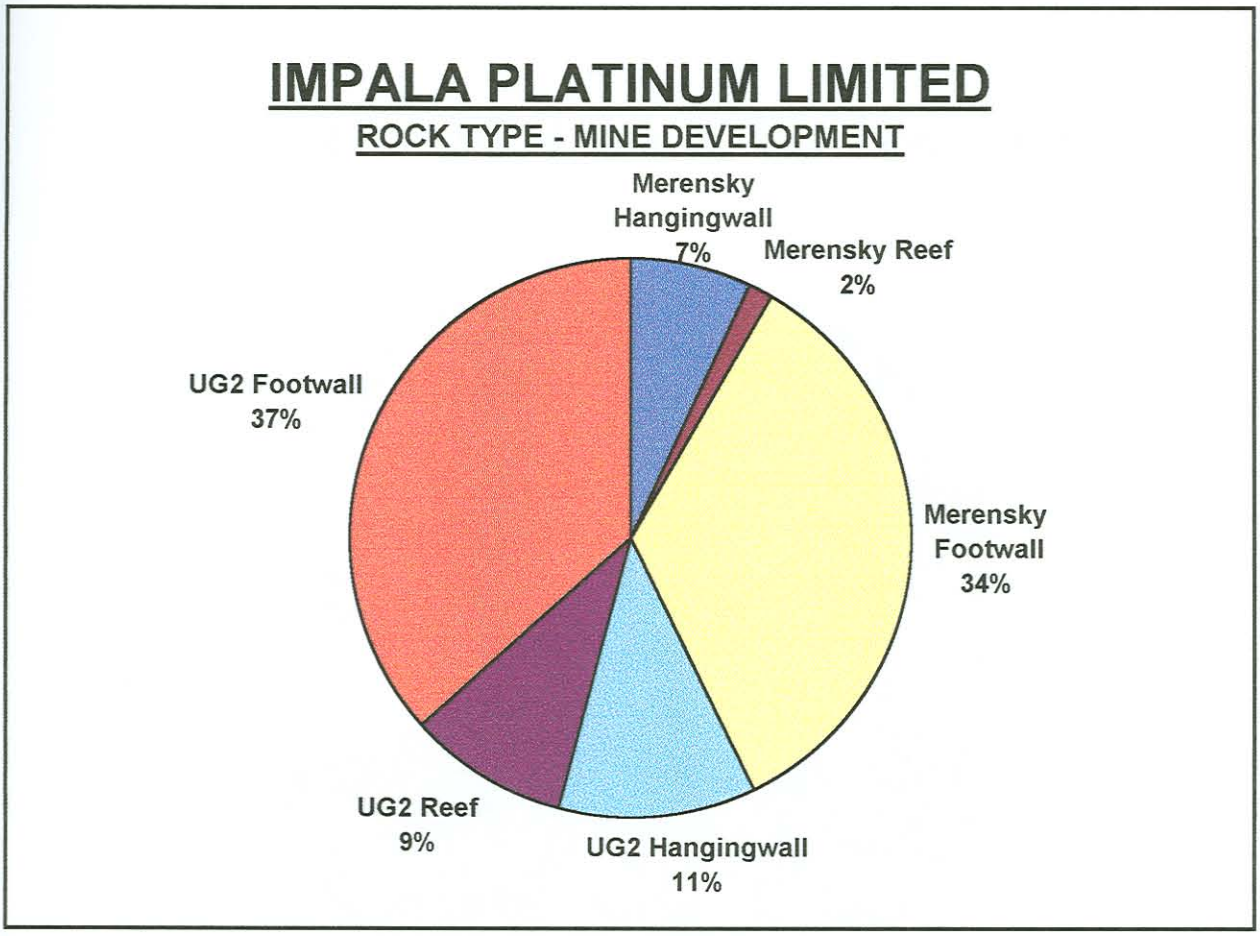

FIG. 3.8 - Rock type falls of ground in mine development

Figure 3.9 shows a pie chart of the typical boundaries responsible for reportable and fatal fall of ground accidents in mine development from 1992 to 1996. Thus 63% of the falls of ground occurred with jointing as boundaries, 27% were chromitite layers, 6% faults and 4% Dykes. Therefore the rockmass classification used at Impala must include joint analysis, as the majority of falls of ground are bounded by joints.

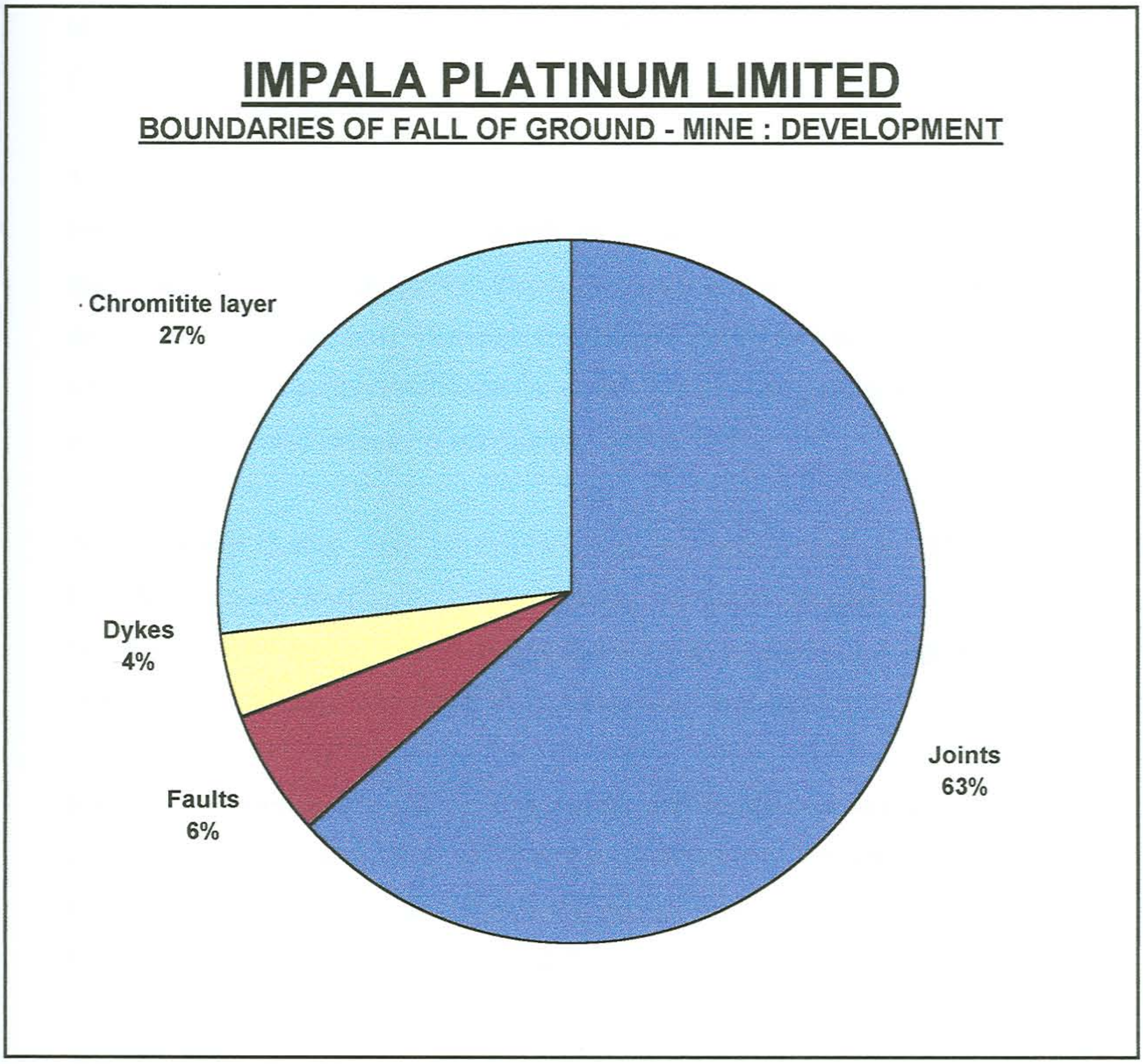

FIG. 3.9 - Boundaries of falls of ground in mine development