

**Safety in Mines Research Advisory Committee**

**Final Project Report**

**Updating and maintaining the  
accident database**

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# Table of contents

	Page
1 Introduction.....	6
2 Methodology .....	7
3 Data Analysis and Results .....	8
3.1 Fatalities by reef .....	8
3.2 Production.....	8
3.3 Fatality trends analyses by reef and in comparison to previous years .....	10
3.4 Analysis by location of fatality .....	16
3.5 Ratio of rockburst to rockfall fatalities .....	17
3.6 Review of number of fatalities per incident.....	19
4 Conclusions and recommendations.....	21

# List of figures

	<b>Page</b>
Figure 1. Distribution of fatalities by reef.....	8
Figure 2. Production by reef.....	9
Figure 3. Fatality rate for all rock related accidents (All fatalities) .....	11
Figure 4. Fatality rate for all reefs (Stopping only) .....	12
Figure 5. Fatality rate for Carbon Leader Reef .....	12
Figure 6. Fatality rate for Ventersdorp Contact Reef.....	13
Figure 7. Fatality rate for Vaal Reef .....	13
Figure 8. Fatality rate for Basal Reef .....	14
Figure 9. Fatality rate for the Kimberley reefs.....	14
Figure 10. Fatality rate for the Composite and Main reefs.....	15
Figure 11. Fatality rate for 'Other' reefs .....	15
Figure 12. Distribution of fatalities by location .....	16
Figure 13. Ratio of rockburst to rockfall fatalities for Carbon Leader Reef, Ventersdorp Contact Reef, Vaal Reef and All reefs .....	18
Figure 14. Ratio of rockburst to rockfall for Basal Reef, Kimberley Reef, Composite/Main reefs and 'Other' reefs .....	18
Figure 15. Distribution of number of fatalities caused by single and multiple fatality incidents (stopes and other excavations).....	20
Figure 16. Percentage of total fatalities resulting from multiple fatality incidents and the ratio of rockburst to rockfall fatalities .....	21

## List of tables

	<b>Page</b>
Table 1. Rockburst and rockfall fatalities, and production and fatality rate .....	9
Table 2. Comparison of the percentage distribution of locations in 1999 with previous years.....	17
Table 3. Ratio of rockburst to rockfall by reef and the mean.....	19

# 1 Introduction

A database was developed in 1990 to store and allow analysis of information on rockfall and rockburst fatal accidents that have occurred in the South African gold mining industry. The information populating the database is extracted from the inquiry reports compiled by the inspectorate of the Department of Minerals and Energy. Also included in the database is the annual production, expressed as m<sup>2</sup> mined, for each of the reefs mined. The production data is used as a normalizing factor in the analysis of the accident statistics. This normalization nullifies the effect of varying production levels during the period under review and of different reefs.

This SIMRAC project, GAP 727, "accident database update", entails the collection of fatality and production data for the gold mines for 1999 and the inputting of this data in the database kept at CSIR: Miningtek. CSIR: Miningtek funded and organised the collection of data for 1998. This report covers the analyses carried out on data collected.

The objectives of the analyses are, inter alia, to determine trends with time in fatality rates; in the occurrence of rock related accidents with respect to working place; and in the ratio of rockburst to rockfall accidents, bearing in mind the difference in the behavior of different reefs. In order to optimize the relevance of the analyses, the reefs in which major production occurs are treated separately. These reefs are the Carbon Leader Reef, VCR, Vaal Reef, Basal Reef, Main/Composite reefs and Kimberley reefs. A category, 'Other Reefs' has been created for data on reefs of lesser production significance. This is the first year that the data for the Kimberley reefs and Main reefs have been analysed separately.

The main objective of these analyses is to gain insight from the rockburst and rockfall related fatality information into the causes of accidents in the South African gold mining industry during 1999 as well as to determine the contributing factors. This information is also compared with information from previous years (i.e. 1990 – 1998). Consideration of these results will assist in highlighting topics which require further research or where the implementation of various rock engineering strategies warrant investigation.

## 2 Methodology

The fatality data that was extracted from the SAMRASS information was obtained from the DME in Pretoria. Since this data does not include all the required parameters, the regional DME offices were contacted and visited for additional data from the proceedings of official inquiries into the fatal accidents. These proceedings consisted of statements and reports from the responsible officials such as the mine manager, rock engineering practitioner, mine inspector, as well as the witnesses' reports and a detailed survey plan showing the location of the fatal accident, support layout, distance of the victim to the face, geological anomalies, etc. These reports were carefully read and the mine plans scrutinized in order to establish the cause of the accident as well as the contributing factors. The parameters that were examined and which it is believed have major impact on the occurrence of the fatal accidents included:

- Whether the accident was a rockburst or rockfall
- Adherence to support standards
- Reef mined and the dimensions of the responsible fall
- Location of the accident – tunnel, stope, gully, etc.
- Distance to the work face

All the required data was captured from the DME offices using a specially designed form. The data was then fed into the database program for analysis.

Production of each mine, in term of square metres mined, by (a) month (b) reef and (c) shaft was obtained from the mines with the permission of the mine manager concerned or the chief surveyor. This data was then summed for each reef and the casualty data was normalized and expressed as “fatalities per million square metres mined”. Normalization of the data negates the fluctuation in the number of people working underground over time. No data was readily available as to production in various depths categories for each reef. This prevented any analysis that would accurately and reliably determine the influence of mining depth on safety, the occurrence of rockbursts, etc. This is a serious deficiency in the information available in the industry.

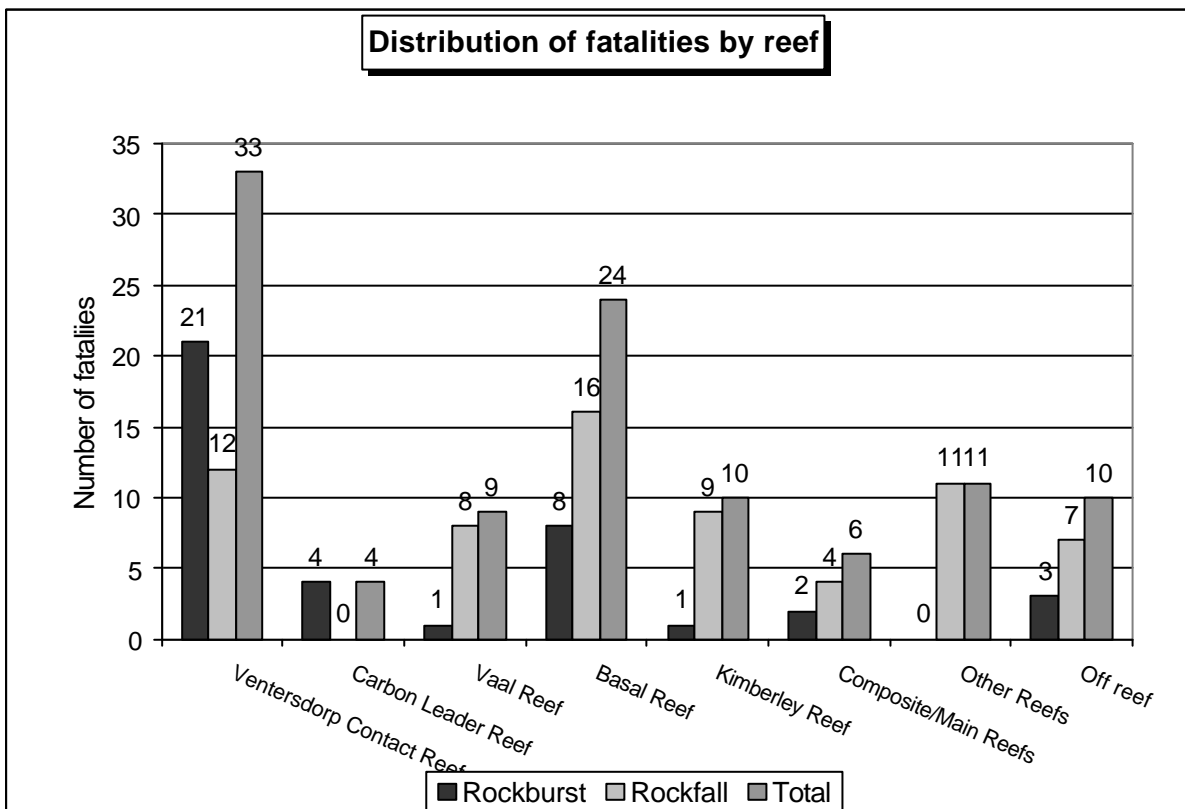
The output of this project is to maintain and expand the database which is held by CSIR: Miningtek.

### 3 Data Analysis and Results

#### 3.1 Fatalities by reef

A total of 107 rock related fatal accidents occurred in the gold mining industry during 1999. Of these 37.4 % were due to rockbursts and 62.6 % were due to rockfalls.

**Figure 1** illustrates the number of fatalities that occurred on the various reefs. From this, it is seen that the VCR is the reef which had the most fatalities with the majority occurring as a result of rockbursts.



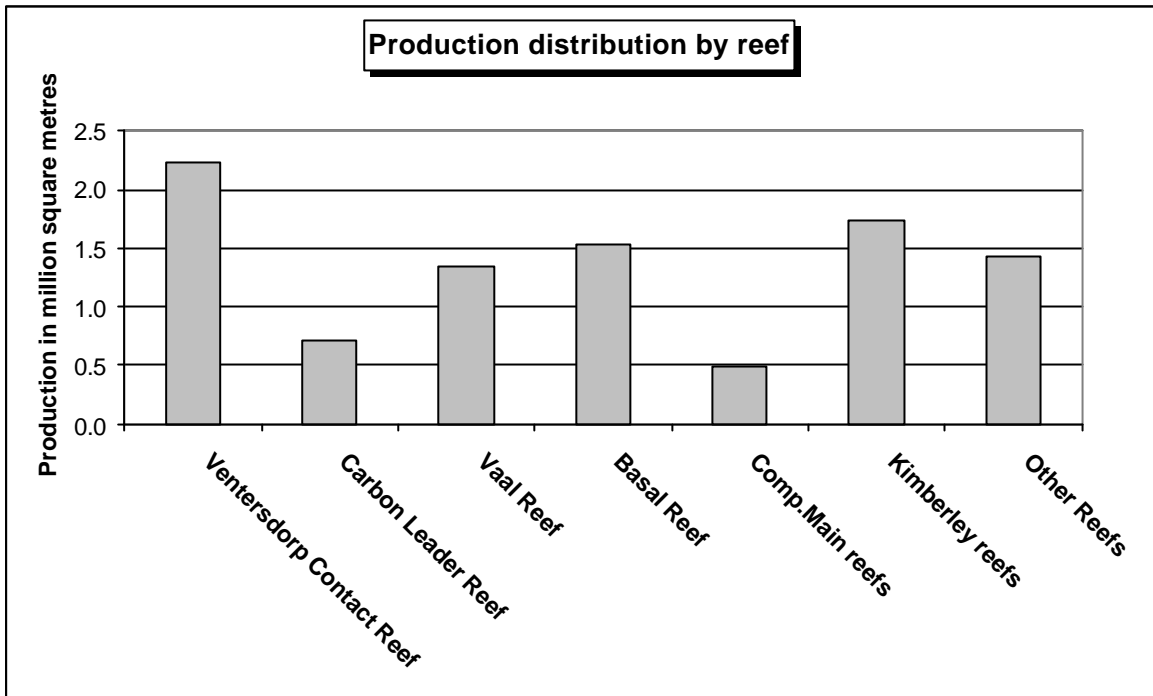
**Figure 1. Distribution of fatalities by reef**

#### 3.2 Production

A total of approximately 9.5 million square metres was mined by the gold mining industry during the year 1999. Figure 2 shows the distribution of production in square metres by



reef. From this, it is seen that the VCR has the highest production, followed by the Kimberley reefs and the Basal Reef.



**Figure 2. Production by reef during 1999**

Table 1 shows the fatality rates for the year 1999 (fatalities per million square metres mined). The fatality rate ranges from 5.6 for the Carbon Leader to 15.6 for the Basal Reef.

**Table 1. Rockburst and rockfall fatalities, production and fatality rate (fatalities / 10<sup>6</sup> m<sup>2</sup>) for 1999**

Reef type	Rockburst Fatalities	Rockburst Fatality Rate	Rockfall Fatalities	Rockfall Fatality Rate	Total Fatality Rate	Production (m <sup>2</sup> )
Ventersdorp Contact Reef	21	9.4	12	5.4	14.7	2 240 384
Carbon Leader Reef	4	5.6	0	0.0	5.6	709 574
Vaal Reef	1	0.7	8	6.0	6.7	1 337 258
Basal Reef	8	5.2	16	10.4	15.6	1 535 855
Kimberley reefs	1	0.6	9	5.2	5.8	1 736 558
Composite/Main reefs	2	4.0	4	8.0	12.0	498 047

Other reefs	0	0.0	11	7.7	7.7	1 434 979
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### 3.3 Fatality trends analyses by reef and in comparison to previous years

The annual fatality rates (fatalities per million square metres mined) incorporating all rock related accidents that occurred in the gold mining industry are depicted in histogram form in Figure 3 for the last 10 years. Figure 4 is similar to Figure 3 but is limited to accidents that occurred in stopes. Fatalities caused by rockbursts and rockfalls are shown separately and also in combination for various reefs (Figure 5 to Figure 11).

It can be seen that the Carbon Leader Reef, which previously had a fatality rate of about 30, had an exceptional year in 1999 when the rate was significantly improved to a figure of 5.6.

Over the five years up to 1999 the fatality rate on the VCR remained almost static at about 15.

In 1999 the trend for the Vaal Reef was reversed and the rate dropped significantly to 6.

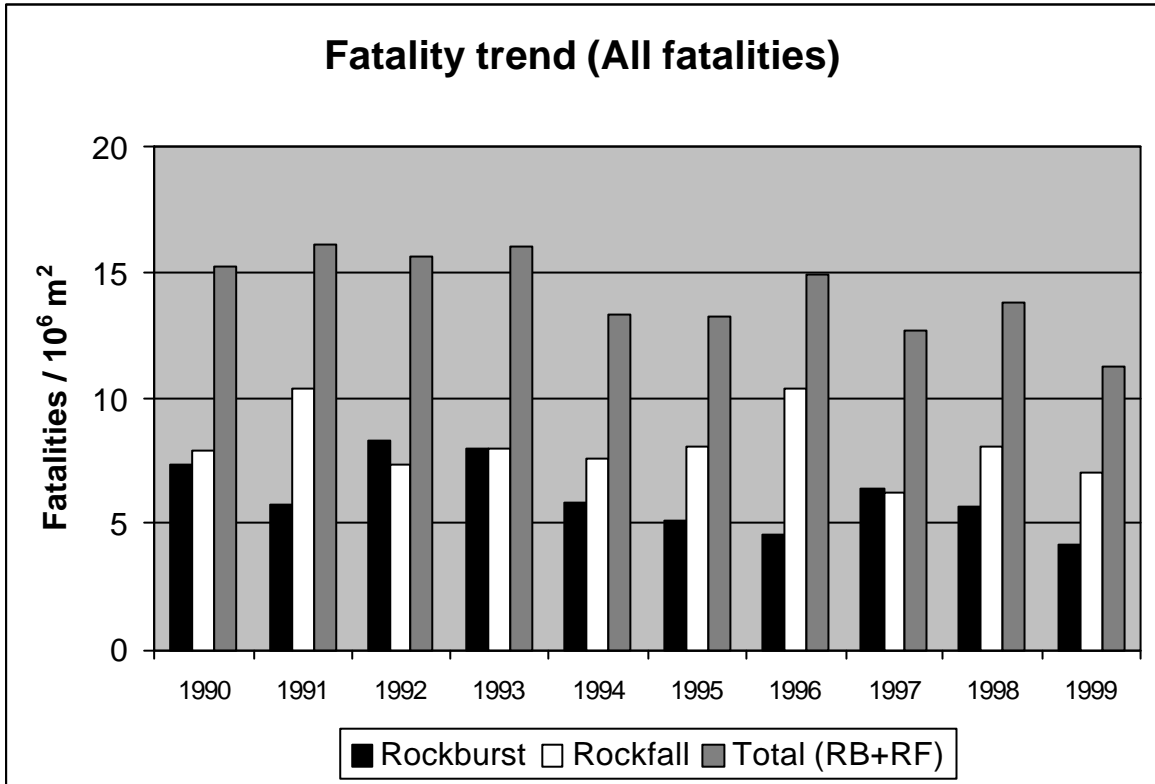
The downward trend on the Basal Reef between 1995 and 1998 reversed in 1999. The rate of 15.6 is the worst for any reef in 1999. This followed two years with a relatively good safety record.

The area mined on the various Kimberley reefs is second only to that on the VCR. The fatality rate is the lowest of all major reefs varying between 1 and 5. In 1999 the figure was 4.6 fatalities per million square metres mined with rockbursts contributing about 10 % of the total.

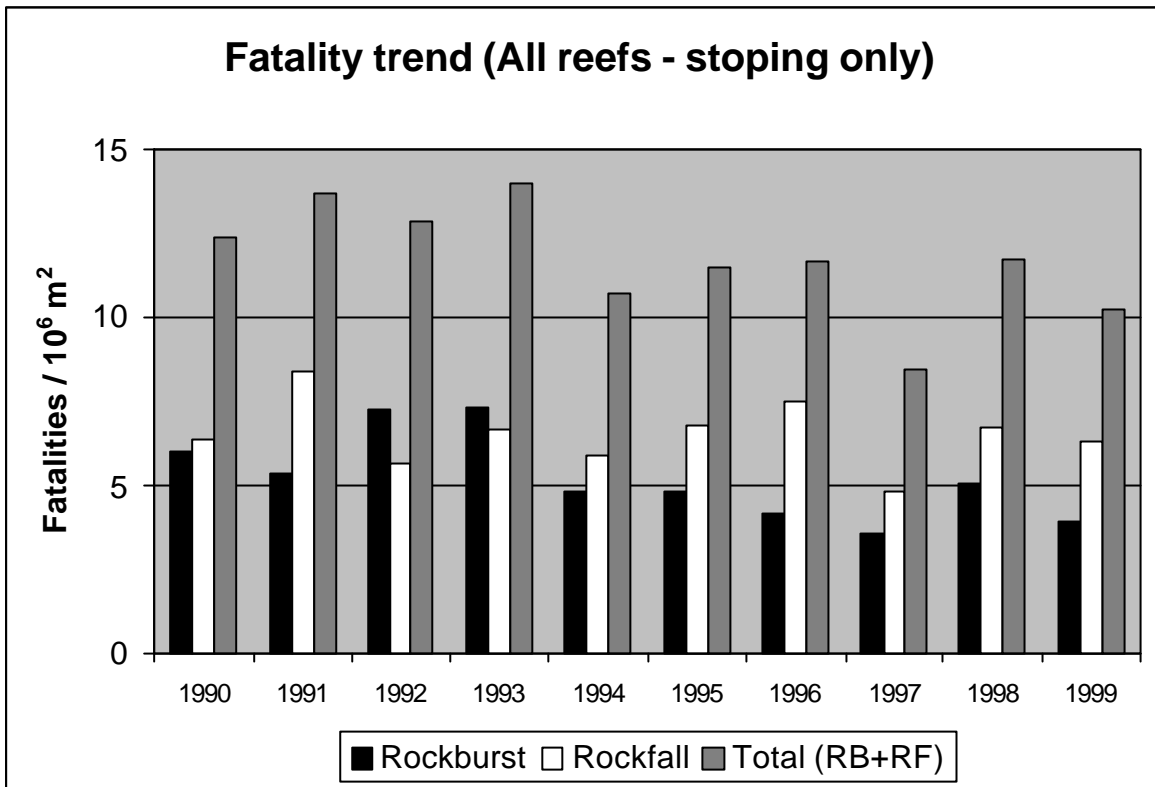
The fatality rates on the various Main reefs mined across the industry are 30% lower between 1995 and 1999 than in the previous 5 years and are similar to the industry average. The decline is probably due to the decrease in average depth of mining over the past few years, as indicated by the reduced ratio of rockbursts to rockfalls. However, in

1999 there was a deterioration in the safety record to a rate of 12 fatalities per million square metres mined. This was due to an increase in both rockfall and rockburst accidents.

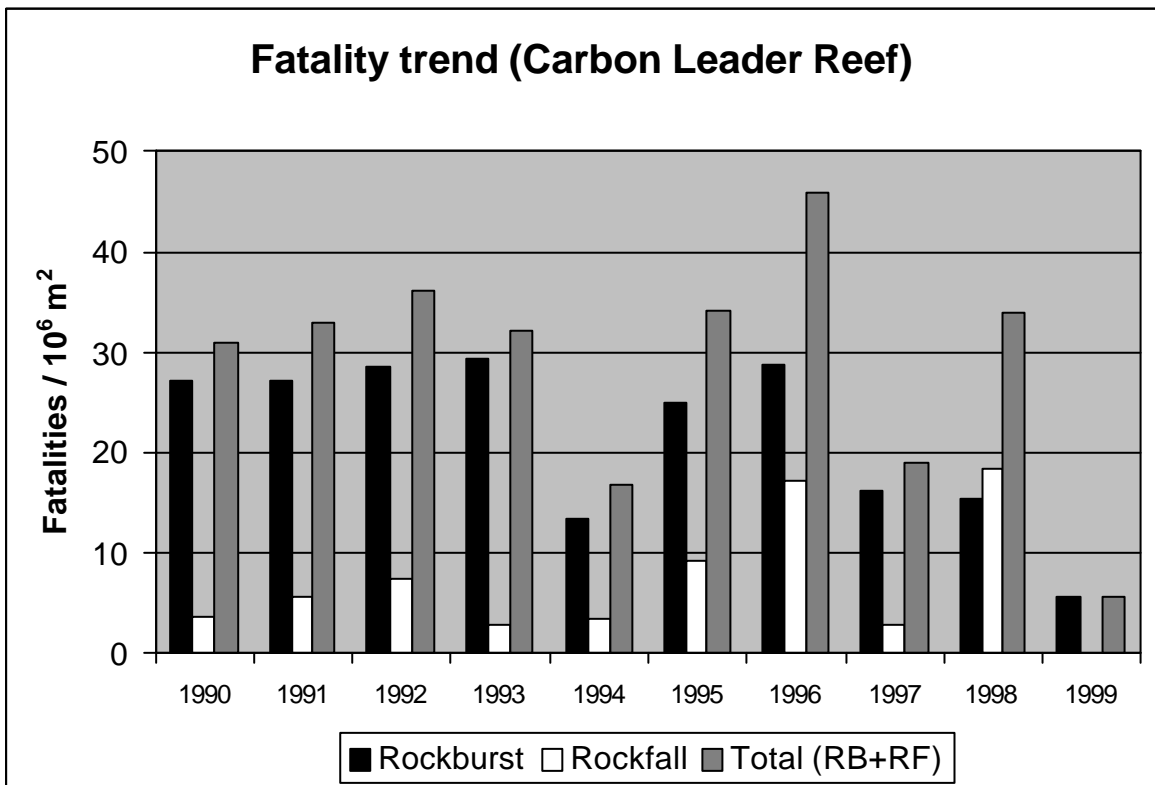
The fatality rates for the 'Other Reefs' category have been fairly consistent over the past four years and at about seven are significantly lower than they were in the early 1990's.



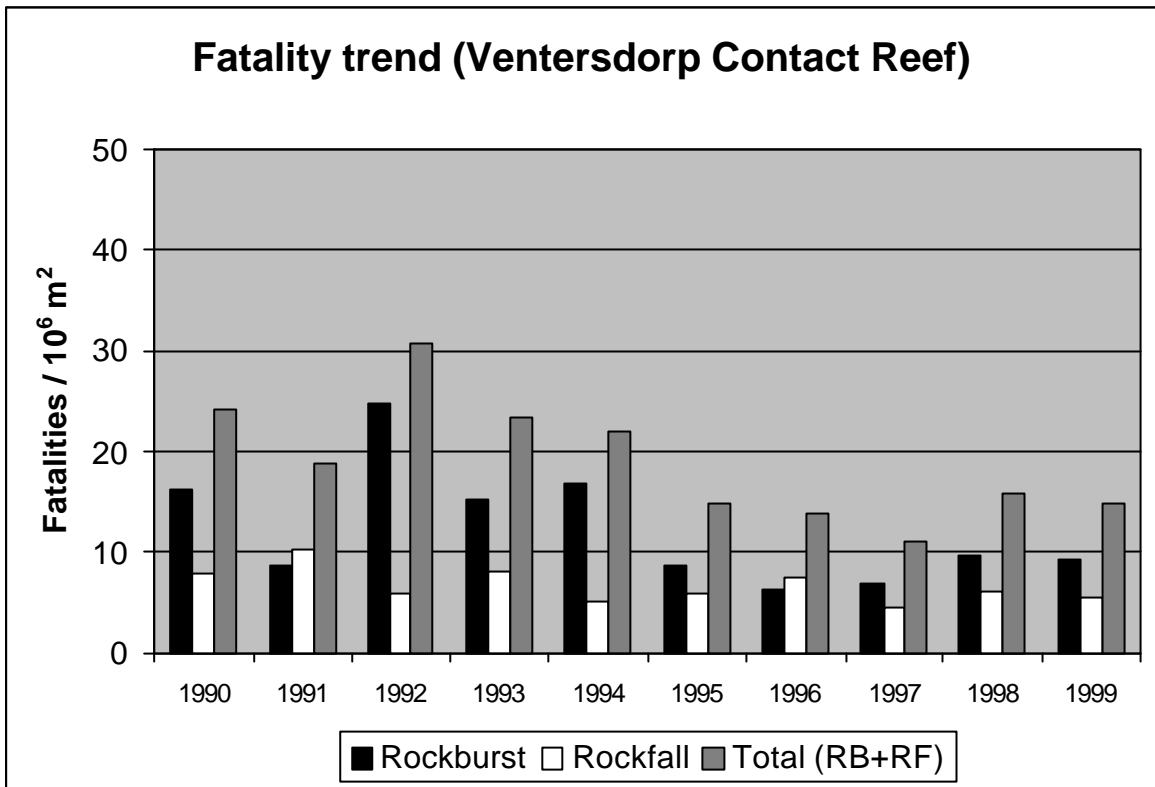
**Figure 3. Fatality rate for all rock related accidents (All fatalities)**



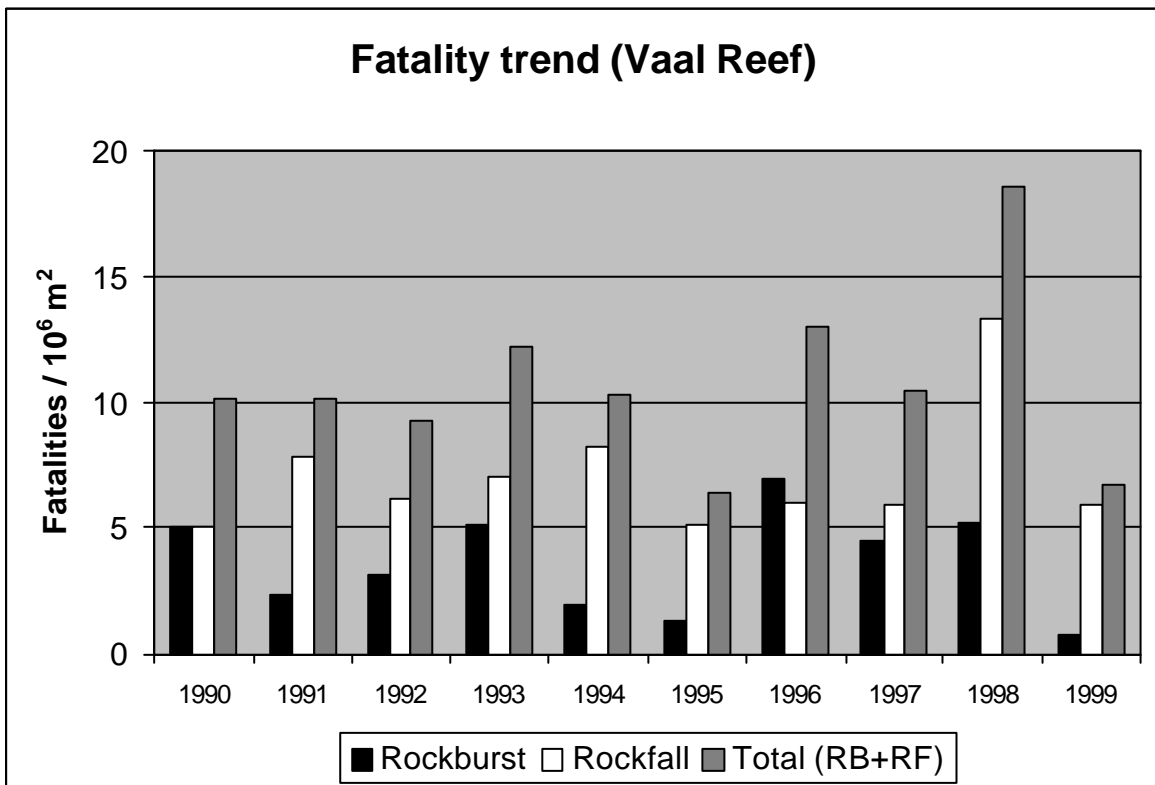
**Figure 4. Fatality rate for all reefs (Stoping only)**



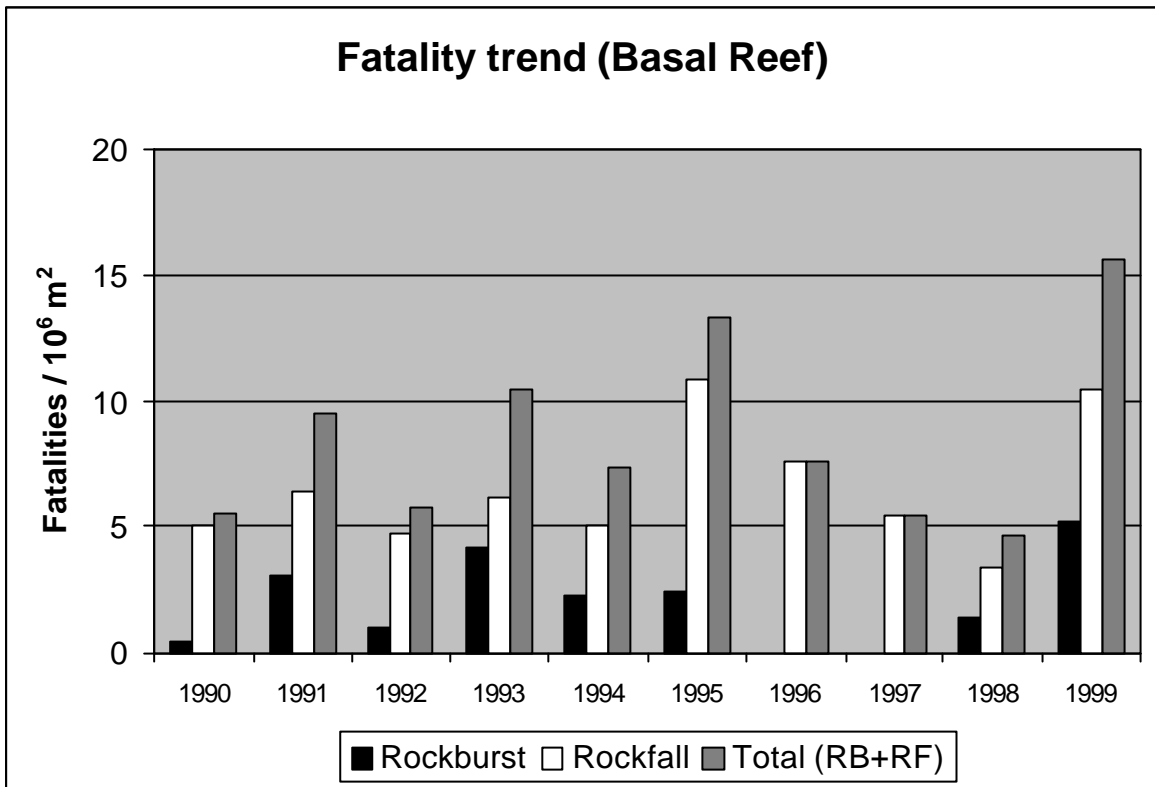
**Figure 5. Fatality rate for Carbon Leader Reef**



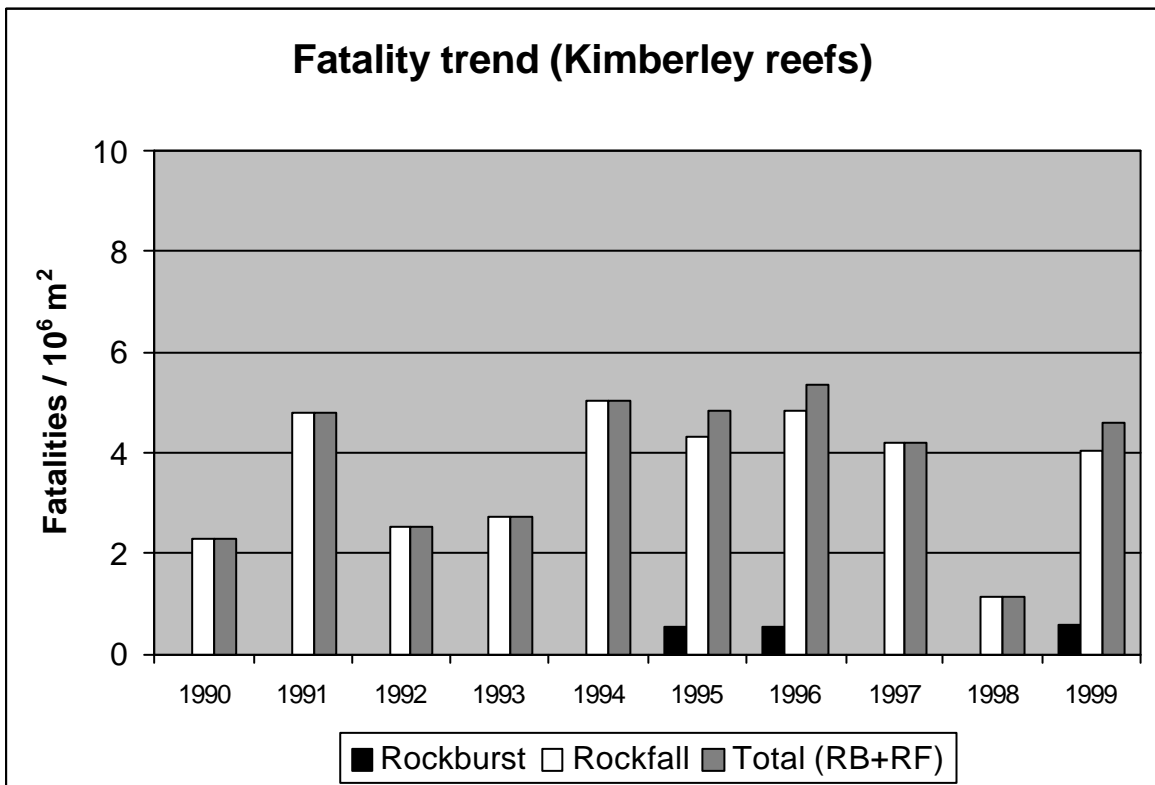
**Figure 6. Fatality rate for Ventersdorp Contact Reef**



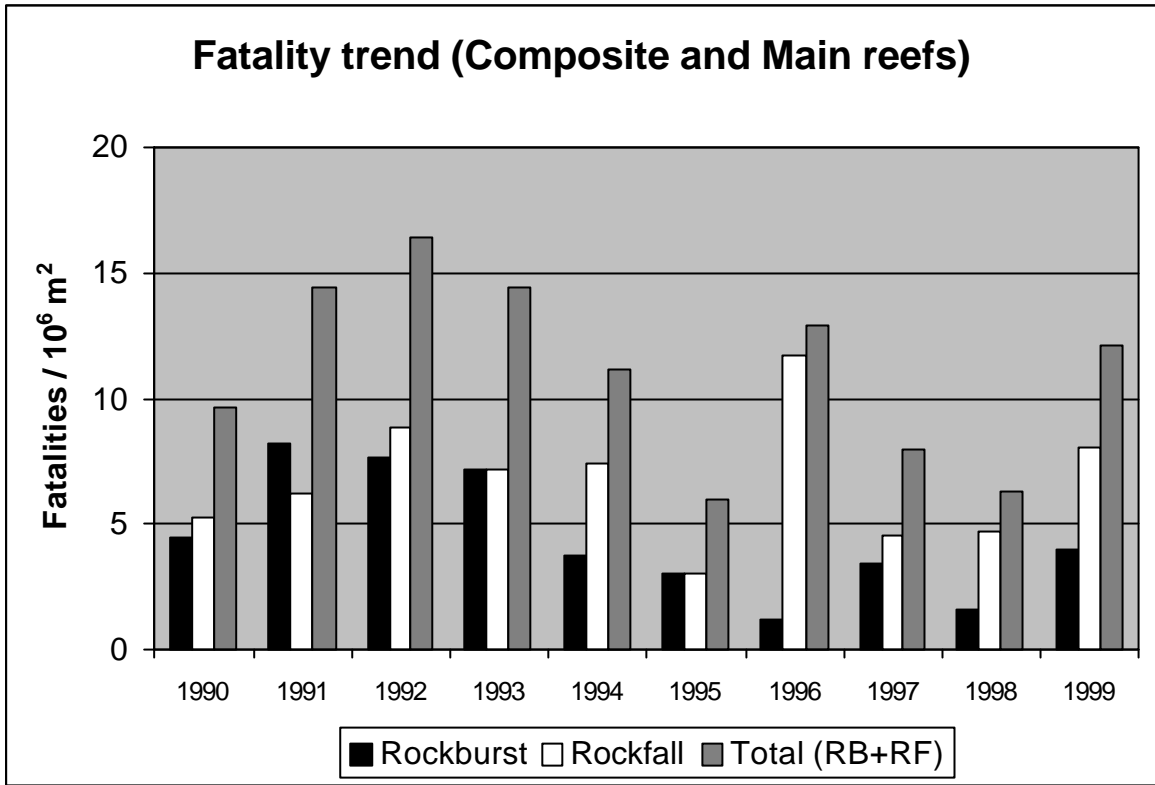
**Figure 7. Fatality rate for Vaal Reef**



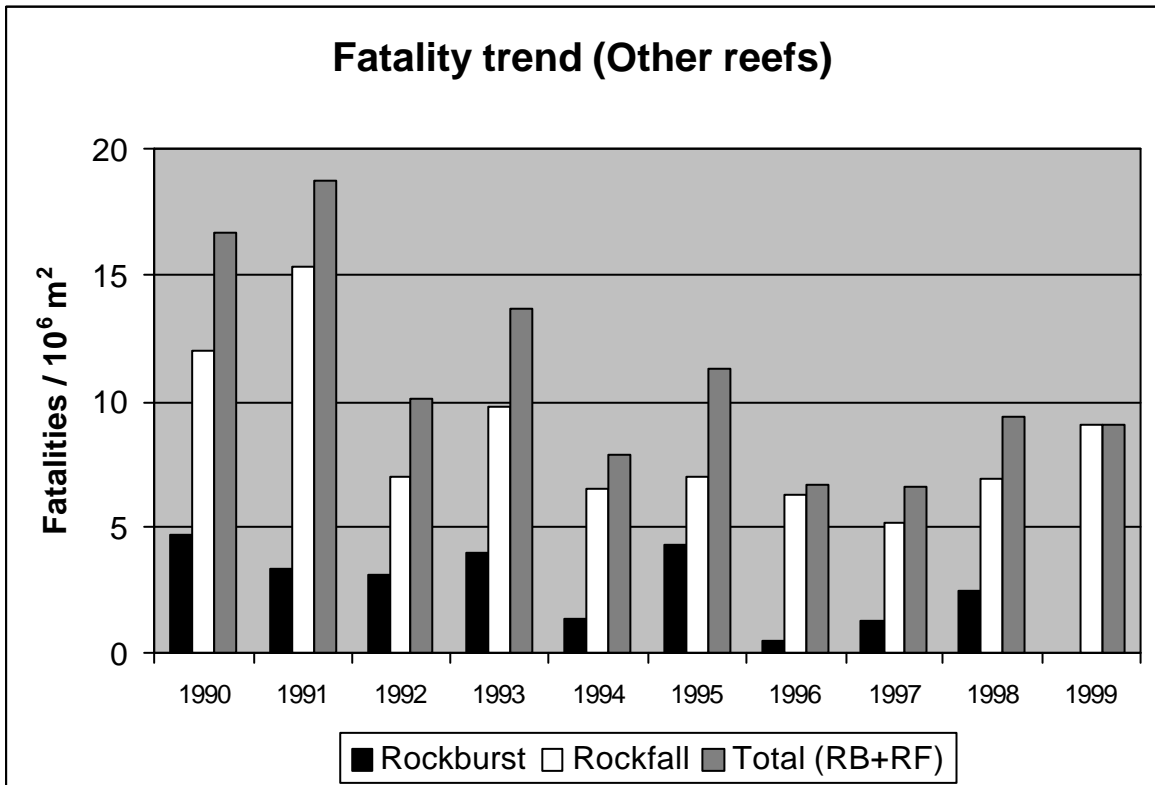
**Figure 8. Fatality rate for Basal Reef**



**Figure 9. Fatality rate for the Kimberley reefs**



**Figure 10. Fatality rate for the Composite and Main reefs**



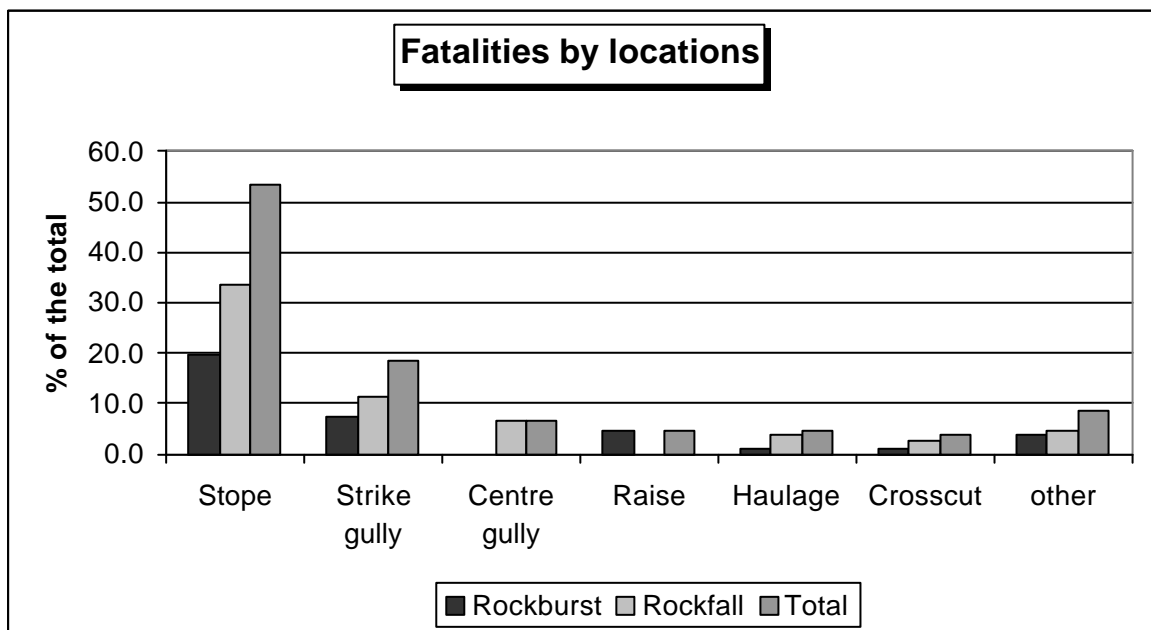
**Figure 11. Fatality rate for 'Other' reefs**

### 3.4 Analysis by location of fatality

Figure 12 shows the percentage of rock related fatalities that occurred in various categories of working place. The data for 1999 is compared to the average for the previous years (i.e. 1990 – 1998) in Table 2. It is evident that the major problem area remains the stope face where 53.3 % of rock related fatalities occurred in 1999. This is 0.7 % less than for previous years (Roberts et al, 2001) showing very little relative improvement in the stope face area.

The strike gully leading to the face is associated with the second highest number of fatalities. The situation in gullies has deteriorated compared to the average of the previous years. In 1999 accidents in the gullies comprised 25.2 % of the total compared to the prior average of 19.4 % and indicates that gully fatal accidents are becoming, relatively, more of a problem.

The percentage of fatalities in raises, comprised 4.7 % of all fatalities in 1999. This data has not been extracted before.



**Figure 12. Distribution of fatalities by location**

Overall, the fatalities in tunnels and other off reef excavations were lower in 1999: 16.8 % compared to 26.6 % in previous years.



Table 2 compares the percentage of fatalities by location in 1999 with the previous years (1990 to 1998). From the table, it is evident that the rockburst fatalities in stope panels have dropped from 24.4 % to 19.6 %. However, the percentage of rockfall cases in strike gullies has increased from 6.8 % for 1990 to 1998 to 11.2 % in 1999. The rockburst fatalities in drives, haulages and crosscuts were less in 1999 than in the previous years. All the fatalities in raises were as a result of rockbursts.

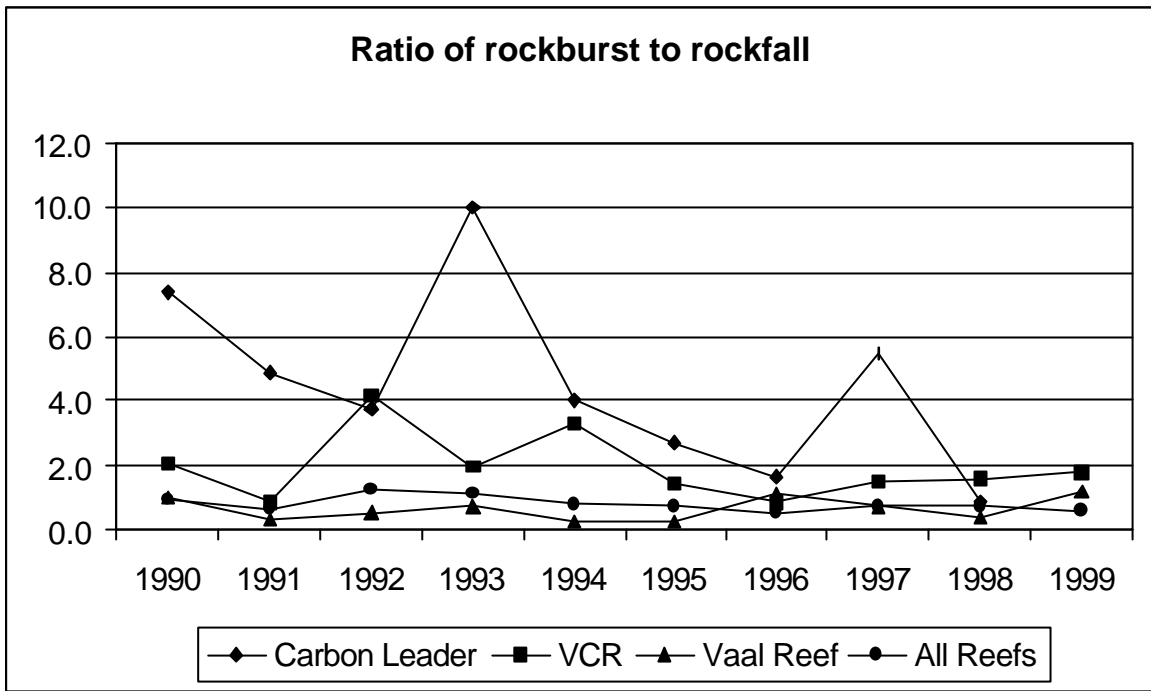
**Table 2. Comparison of the percentage distribution of locations in 1999 with previous years.**

Location	1999			1990 - 1998		
	Rockburst	Rockfall	Total	Rockburst	Rockfall	Total
Stope	19.6	33.6	53.3	24.4	29.6	54
Strike gully	7.5	11.2	18.7	8.6	6.8	15.4
Centre gully	0	6.5	6.5	1.5	2.5	4
Raise	4.7	0.0	4.7	-	-	-
Crosscut	0.9	2.8	3.7	2.1	4.4	6.5
Drive/ Haulage	0.9	3.7	4.7	3.1	3.1	6.2
Other	3.7	4.7	8.4	5.1	8.8	13.9
Total %	37.4	62.6	100	44.8	55.2	100

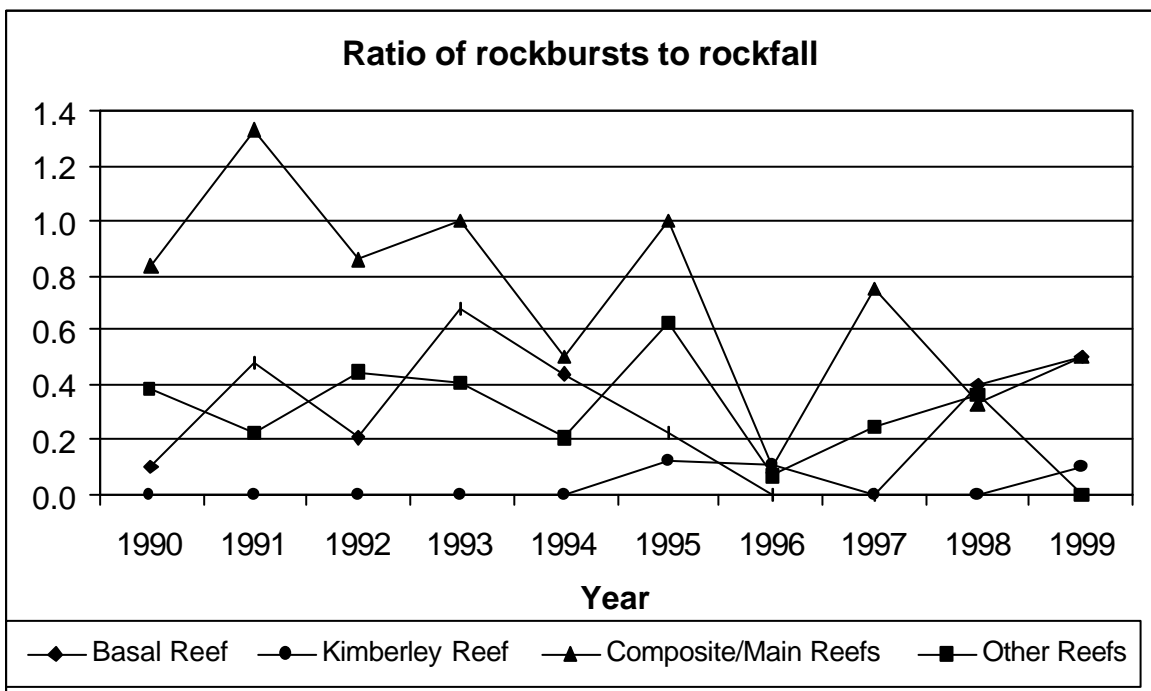
### 3.5 Ratio of rockburst to rockfall fatalities

The influence of rockbursts on fatality rate is shown in Figure 13 and Figure 14, where the rockburst to rockfall ratio is plotted for each reef and also for each year. This shows that, until 1997, the Carbon Leader Reef experienced the highest relative incidence of rockbursts fatalities compared to other reefs. In 1998, the ratio dropped to less than 1. In 1999 the relatively low number of fatalities that occurred, 4, were all as the result of rockbursts.

Table 3 shows the ratios by year and by reef. Also shown in the table is the mean value and the standard deviation for the period. It is evident from the table that the mean values for the Carbon Leader Reef, VCR and Main reefs over the later period are approximately half those which prevailed in 1990 – 1994. It would be useful to research the cause of this difference if the figures are statistically significant.



**Figure 13. Ratio of rockburst to rockfall fatalities for Carbon Leader Reef, Ventersdorp Contact Reef, Vaal Reef and All reefs**  
 (Note no rockfall fatalities on Carbon Leader Reef in 1999)



**Figure 14. Ratio of rockburst to rockfall for Basal Reef, Kimberley Reef, Composite/Main reefs and 'Other' reefs**

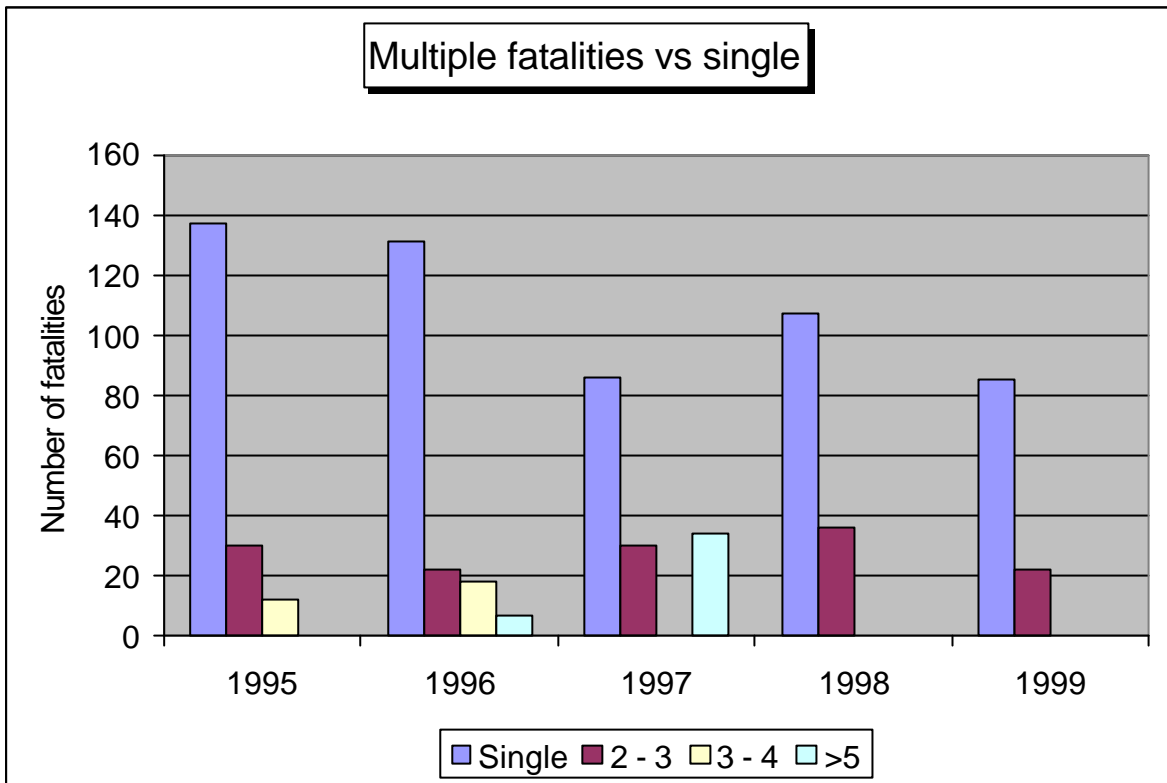
**Table 3. Ratio of rockburst to rockfall by reef and the mean.**

	Carbon Leader Reef	Ventersdorp Contact Reef	Vaal Reef	Basal Reef	Kimberley reefs	Comp./Main reefs	Other reefs	All reefs
1990	7.4	2.1	1.0	0.1	0.0	0.8	0.4	0.9
1991	4.9	0.9	0.3	0.5	0.0	1.3	0.2	0.6
1992	3.8	4.1	0.5	0.2	0.0	0.9	0.5	1.3
1993	10.0	1.9	0.7	0.7	0.0	1.0	0.4	1.1
1994	4.0	3.3	0.2	0.4	0.0	0.5	0.2	0.8
<b>Ave</b>	<b>6.0</b>	<b>2.5</b>	<b>0.6</b>	<b>0.4</b>	<b>0.0</b>	<b>0.9</b>	<b>0.3</b>	<b>1.0</b>
<b>Standard Deviation</b>	<b>2.4</b>	<b>1.1</b>	<b>0.3</b>	<b>0.2</b>	<b>0.0</b>	<b>0.3</b>	<b>0.1</b>	<b>0.2</b>
1995	2.7	1.5	0.3	0.2	0.1	1.0	0.6	0.7
1996	1.7	0.8	1.2	0.0	0.1	0.1	0.1	0.5
1997	5.5	1.5	0.8	0.0	0.0	0.8	0.3	0.7
1998	0.8	1.6	0.4	0.4	0.0	0.3	0.4	0.8
1999	Undefined *	1.8	1.2	0.5	0.1	0.5	0.0	0.6
<b>Ave</b>	<b>2.7</b>	<b>1.4</b>	<b>0.7</b>	<b>0.2</b>	<b>0.1</b>	<b>0.5</b>	<b>0.3</b>	<b>0.7</b>
<b>Standard Deviation</b>	<b>1.8</b>	<b>0.3</b>	<b>0.4</b>	<b>0.2</b>	<b>0.1</b>	<b>0.3</b>	<b>0.2</b>	<b>0.1</b>

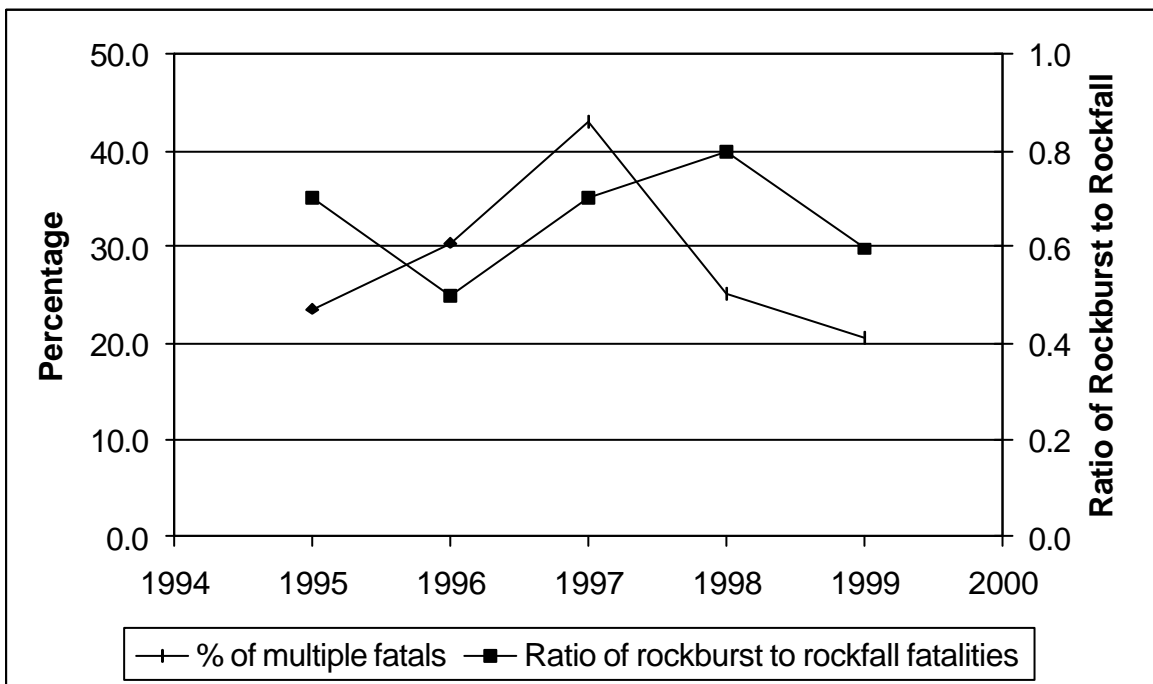
\* No Rockfall fatalities.

### 3.6 Review of number of fatalities per incident

A type of analysis not performed previously was carried out to determine what proportion of rock related fatalities are caused by multiple fatality incidents. Figure 15 shows the number of people killed in various size categories of multiple fatality incidents. The data is shown in histogram form for the period 1995 – 1999. Figure 16 shows the percentage fatalities resulting from multiple fatality incidents with respect to total fatalities. The annual percentage varied between 24 % and 42 % over the period. 2 and 3 fatality incidents comprise 19.7 % of the total, 4 and 5 fatality incidents 3.9 % and > 5 fatality incidents 5.3 %. The largest number of people killed in a single incident over the period was 18. This incident was a rockburst that effected a crosscut. The percentage of multiple fatalities that occurred in stopes was 64.5 % and in other excavations 33.5 %. The distribution of single fatalities was 81.9 % and 19.1% respectively.



**Figure 15. Distribution of number of fatalities caused by single and multiple fatality incidents (stopes and other excavations)**



**Figure 16. Percentage of total fatalities resulting from multiple fatality incidents and the ratio of rockburst to rockfall fatalities**

## **4 Conclusions and recommendations**

The objective of maintaining and expanding an accident database is to review rock related fatality statistics and trends. The database contains detailed information on all rockfall and rockburst related fatal accidents since 1990. The results of analyses of the data include the identification of potential hazardous reefs and work places, which will assist in focusing research on problematic areas.

Based on the findings of this work, the following conclusions can be drawn:

- The overall rock related fatality rate in 1999 was slightly better than in previous years.
- Safety on the Carbon Leader Reef improved significantly in 1999 while the opposite occurred for the Basal Reef which, in 1999 experienced the worst fatality rate of all reefs. If these trends continue into 2000, the reasons need to be identified so that mining on other reefs can benefit from the strategies used on the Carbon Leader Reef mining and to enable the problems on the Basal Reef to be identified and solved.
- Stope faces persist in being the working place where most fatalities occur. Although this is to be expected because of the high risk factor (personnel density in this area), the insignificant change in this statistic is of concern as the industry has focused on improving safety in this area. This matter requires further investigation.
- The percentage of fatalities occurring in gullies increased from 19.4 % for the period 1990 - 1998 to 25.2 % in 1999. The majority (70 %) were due to rockfalls, where previously this percentage was 48 %. If these figures confirm a
- deterioration in gully safety, then further research into means of improving the stability of gullies appears necessary.

- The proportion of fatalities in multiple fatality incidents has varied between 23 % and 42 % of the total.
- The ratio of rockburst to rockfall fatalities appears to be declining, reaching a low of 0.7 in 1999. The reasons for this are unclear and need to be investigated. Contributing factors could include: better implementation of improved layouts; the positive effect of long term backfilling placed more effectively; increase in strategically implemented preconditioning; a smaller decline in rockfall fatality rates (a disturbing factor indicating little improvement in the implementation of better support); less mining in rockburst prone ground or at greater depths.
- Concerning the production at various depths, there is no readily accessible data. A mechanism should be put in place to provide and collate such data.
- The platinum mines are contributing an increasing proportion of tabular hard rock mining production and data from these mines should be included in the database.
- Data on 2057 fatalities which occurred in gold mines between 1990 and 1999 reside in the database. A thorough statistical and analytical study of this information, comparing earlier data with later data, should provide useful insights into the effectiveness of various rock engineering strategies and highlight current research priorities.

## References

**Jaku, E.P, Jager A.J., & Roberts M.K.C (2001)** A review of rock related fatality trends in the South African Gold Mining industry. 38<sup>th</sup> American Rock Mechanics Symposium.