INTRODUCTION

The current industry regulations and guidelines call for systematic underground support that is capable of resisting 95% of all potential falls of ground as determined by statistical analysis. In the last 12 years the data obtained from fall of ground accidents (including fatalities) at Impala Platinum Mine is limited in off-reef excavations compared to the stoping horizon. The cost to support the excavations systematically to a 50kN/m² was therefore considered unacceptable. A more acceptable design criterion was required for the mine's problem. Various rockmass classification systems were suggested by numerous consultants. However the rockmass classification system is just intended for the use or application to the specific problem identified, therefore further research was necessary to ensure that a design system or rockmass classification system leading to a bolt design system is applicable to the Impala problem.

Impala Platinum Mine is situated 23km North of the town Rustenburg and covers approximately 25 km on strike from the most southern to the most northern shaft. The mine is currently mining the Merensky reef and the UG2 reef for platinum group metals and various other by products. Both the Merensky reef and the UG2 reef are part of the Bushveld Igneous Complex. The Merensky reef consists of pyroxenite and pegmatoid units and the UG2 Chromitite seam consists of chromitite and pegmatoid units. The Merensky reef overlays the UG2 Chromitite seam by 60m in the north , increasing to a 130m middling towards the south. The general strike of these orebodies is north-northwest to south-southeast. Local variations in the orebodies can lead to an east-west strike.

The average stoping width mined on the Merensky reef is 1,16m and on the UG2 reef 0,91m. Impala Platinum Ltd. mining depths ranges from 30m to 1200m, with the current mean rock breaking depth of the Merensky reef being 700m below surface and the UG2 mean rock breaking depths at 500m below surface.
Impala produces platinum, palladium, rhodium and nickel and their contribution to mine income is approximately 50%, 22%, 16% and 6% respectively. To ensure that the most current rock mechanics and strata control principles are applied for the safe and

economic design of all mine workings a centralised Rock Engineering function is employed, with it being split into a projects section and an operational section. The operational section's main activities consist of planning and design, risk assessment and strata control. The projects section main activities consist of life of mine design, large excavation stability, new mine prospects and seismic network analysis.

With mine tunneling on Impala throughout the 13 shafts it is impossible to visit each and every development end on a regular basis. Therefore the Impala strata control wing consisting of strata control officers and strata control observers which are mainly functional in the area of information gathering upon which support recommendations are generated. To ensure that these recommendations are made promptly it must be supported by a sound rockmass classification system.

The study of the stability of tunnels in rock is basically a strata control problem in the field of Rock Mechanics and assumes that the rockmass is anisotropic, heterogeneous and discontinuous in nature and that failure tends to be confined to structural discontinuities in shallow tunnels. Rational analysis of tunnel stability in materials with such properties requires that certain geological propositions which are necessary before definition of properties of the tunnel stability can be described, are adopted : (1) that structural discontinuities are detectable and their physical characteristics can be described quantitatively, (2) that within the whole mass it is possible to define smaller masses with similar jointing, (3) that a reliable model representing jointing of a rockmass can be constructed and (4) that the surface of failure will be plane or combinations of planes (Piteau, 1971).

Prerequisite to such an analysis is a qualitative and quantitative deduction of the geology, particularly of the attitude, geometry and spatial distribution of the discontinuities. Since the significant physical and mechanical properties of the mass are, for a large part, a function of the discontinuities, the basic principles on which the studies depend are therefore (1) the systems of jointing, (2) their relationship to possible failure surfaces and (3) strength parameters of the joints. There is an additional very important factor, namely water pressures in the joints. Other factors such as mineralogy, lithology and weathering, high horizontal stresses of tectonic or other origins, natural conditions of tunnels that occur in the vicinity in the same rockmass as the proposed tunnels and effects of time on reduction of strength together with the size and shape of tunnels must also be considered (Piteau, 1971).

Whether a tunnel will be stable or unstable in the same rockmass will depend on the margin by which the forces that tend to resist failure exceed those that tend to cause failure. The stability of tunnels in a stratified rockmass depends largely upon the presence of and nature of the discontinuities within the rockmass.

An underground excavation is an extremely complex structure and the only theoretical tools which the rock engineer has available to assist him in his task are a number of grossly simplified models of some of the processes which interact to control the stability of the excavation. These models can generally only be used to analyse the influence of one particular process at a time, for example, the influence of structural discontinuities or of high rock stresses upon the excavation. It is seldom possible theoretically to determine the interaction of these processes and the rock engineer is faced with the need to arrive at a number of design decisions in which his engineering judgment and practical experience must play an important role (Hoek & Brown, 1980).

Sometimes a project will be fortunate to have an experienced rock engineer on staff who has designed and supervised the construction of underground excavations in similar rock conditions to those being considered, these design decisions can be taken with some degree of confidence. Where no such experience is readily, what criteria can be used to check whether one's own decisions are reasonable ?. The answer lies in some form of classification system which enables one to relate one's own set of conditions to conditions encountered by others. Such a classification system acts as a vehicle which enables a rock engineer to relate the experience on rock conditions and support requirements gained on other sites to the conditions anticipated on his own site (Hoek & Brown, 1980).

A Rockmass classification scheme is intended to be used to classify the rockmass during feasibility and the preliminary design stages of a project (Hoek, 1998). At its simplest this may involve using the classification scheme as a checklist to ensure all relevant information has been considered. Use of a rockmass classification scheme does not (and cannot) replace some of the more elaborate design procedures.

Rockmass classification systems are still qualitative and empirical, rendering then inapplicable to all geotechnical situations. For example, a "poor" rock in a shallow tunnel in shale may need intensive support. A similar shale at greater depth may also be classified as "poor", but the in situ stress state may tend to clamp it, thereby not requiring the intensive support in the former case. Thus rockmass classification systems should be calibrated for every situation they are used in, just as they were for the situation they were developed in.

Relatively detailed information regarding in situ stresses, rock mass properties and planned excavation sequence is required at the initial stages of a project. As this information becomes available, the use of the rock mass classification schemes should be updated and used in conjunction with site-specific analyses.

Most of the multi-parameter classification schemes, like the Rock Structure Rating (Wickham et al, 1972), the Geomechanics Classification from Bieniawski (1973, 1989) and the Q-System from Barton et al (1974) were developed from civil engineering case histories in which all of the components of the engineering geological character of the rockmass were included. These schemes are directly applicable to mining, but many require alterations to suit conditions not yet encountered in civil engineering projects.

Empirical assessments of rock reinforcement and rockmass classification provide a useful supplement to any detailed analytical work. Empirical assessments can be very useful whenever adequate geotechnical data is unavailable for detailed structural analysis or whenever simplified analytical models are inapplicable (Stillborg, 1994).

The aim of this thesis is to contribute to the validation of rockmass classification methods in mining applications with specific reference to Barton's Rock Tunneling Quality Index, Q, which has been in use at Impala Mine since 1993. The classification scheme has been used for underground mine tunneling. This tunneling includes crosscuts, drives, large chambers, chairlift and conveyor decline excavations. The purpose of the thesis is to review rockmass classification systems available and in current use in the civil and mining industries and to compare these with the Q-System for their applicability and choose the best one suitable to the Impala problem. This validation of the Q-system will thus allow the reader to apply it with confidence to a similar geotechnical problem. The modifications required for the Q-System to make it suitable for application to Impala Mine are then discussed.