Chapter 1

1. INTRODUCTION

1.1 GENERAL BACKGROUND

This thesis presents a study of stone floor failure at the underground longwall coal mining face. The study is based on underground measurements, visual observations, analytical work and numerical modelling. Amongst many methods of mining, underground longwall mining is commonly used to mine tabular deposits of coal, because it offers high rates of coal extraction while winning up to 90% of the reserves, and provides one of the safest mining environments for the workforce.

Longwall mining consists of a large number of advancing hydraulic supports holding the roof strata at the edge of coal extraction while a coal cutting machine moves up and down the pillar edge cutting coal. Cut coal is carried on a steel armoured face conveyor to the main gate roadway to be loaded onto the conveyor belt and transported out of the mine. Powered supports control the edge of the caved overburden (goaf edge) and provide confinement stress to the fractured stone roof to minimise excessive rock displacements until roof caving occurs behind the supports. These supports transfer large loads onto the floor via the base pontoons. The method of longwall mining is depicted in Figure 1.
Economic coal reserves are typically located at depths not exceeding 500m below the surface, although some deeper mines exist where the strength of rock is high or economic mining is not feasible.

Coal production from a typical Australian longwall face can currently earn the mine in excess of A$1,000,000 dollars per day, depending on coal quality, coal seam geometry, strength of strata, magnitudes of stress, type of the equipment, and overall efficiency of the longwall operation. Among many
problems that may affect coal production rates are strata failure that can cause chronic deficiency in the expected rate of financial return of the mine. Therefore, it is sensible to maintain an ongoing strata control management program to minimise the risks associated with roof or floor failure.

To minimise disruption of production rates, most strata control design efforts concentrate on roof failure. Even though floor failure does not occur often, under certain conditions, it can cause serious operational problems. Current understanding of floor failure is limited and may not provide solutions to this problem. This thesis intends to advance the knowledge of floor failure in the longwall area and provide the geotechnical engineer with tools to combat the problem.

Floor failure often inhibits longwall mining operations where large displacements of floor strata known as floor heave, interfere with an armoured face conveyor and powered supports. The extent of floor failure depends on rock type and the magnitude of stress concentrations ahead of the face. Floor failure can be divided into primary and secondary failure. Primary floor failure occurs in response to stress concentrations ahead of the longwall face, while secondary failure occurs as stress redistribution and displacements take place at or behind the face line after the floor is exposed.
Primary Floor Failure at or ahead of the Longwall Face

Primary floor fractures induced by high stress concentrations ahead of the longwall face propagate through virgin rock in response to the advancing face. The extent of primary floor failure usually depends on rock strength, bedding strength and the state of ground stress. Although floor failure at longwall faces has been traditionally associated with a weak floor, this study shows that floor failure can be observed in strong rock where weak bedding planes predominate. Primary rock failure that occurs ahead of the face appears to be of a periodic nature, developing continuously or periodically due to stress build up as the coal is cut, which under certain conditions develops into secondary floor failure characterised by large floor displacements. Even though primary failure does not directly cause floor heave, in many instances it does define how secondary floor displacements occur.

Secondary Floor Failure

Stress fields and displacements constantly change as mining progresses. Initially, floor strata are subject to high abutment stress during which primary fractures tend to occur, but as coal is mined, stress relief follows and unloaded floor strata may experience displacements. At this phase of mining, secondary floor failure often occurs that may consist of significant bending and buckling driven by localised stress concentrations and displacements. Secondary floor failure usually occurs at a later stage of mining when strata
movement is reactivated along pre-existing (primary) fracture surfaces. Under certain conditions, these displacements can lead to excessive floor heave that often disrupt coal production. Secondary floor failure is defined as rock failure that develops after primary fractures occur, it is usually influenced by lithology, bedding planes, face geometry, powered hydraulic supports, or modified by either primary failure or subsequent strata displacements.

Secondary failure along bedding planes.

For secondary failure to develop, there must be a driving force within the floor capable of inducing large strains because once initial fractures develop, secondary rock failure follows, and strata deformation continues. In many instances where rock failure propagates along horizontal bedding planes and near vertical fractures, numerous beams, or blocks, form which interact with each other along cohesionless surfaces. Continuous deformation will bend strata and induce tensile, compressive and shear stresses within the fractured rock. Once critical stresses are generated, fractured rock can break into smaller components until a stress/strength equilibrium is reached. During this process, wedging, bending, buckling and hinging may occur resulting in large strains and bulking of broken rock that can seriously influence production rates.

Observed secondary types of floor failure at the longwall face are usually caused by:

- A lateral displacement of yielded coal seam towards the goaf where coal movement generates large lateral stresses within the immediate floor. If
weak bedding planes are present below the floor, the upper floor may buckle,

- Excessive stress at floor level induced by interaction among stone blocks that were formed during primary floor failure,
- Development of tensile breaks due to strata bending,
- Shear displacement along broken material,
- Shear failure along bedding planes,
- Compression failure of thin bedding planes within the floor strata,
- Floor buckling of thin floor layers in stratified rock (usually close to the floor surface),
- Hinged failure of fractured floor consisting of bedded rock,
- Wedging of sheared rock causing floor heave,
- Opening of fractures, and
- Complex combination of any of the above failures.

Floor failure at a longwall face appears to be progressive in nature. Both primary and secondary floor failures appear to be cyclic where floor failure initiates either after every shear is cut, or less frequently, as stress build up occurs. Many types of these floor failures have often caused severe production losses. These problems have been neglected for far too long and there is a need to provide the coal mining industry with rational solutions to minimise these problems.

Even though floor movement in fractured rock can be very complex, the proposed post-failure models given in this study can be used to evaluate the
likelihood of floor failure. In summary, this thesis presents the principles of primary and secondary floor failure mechanisms which are poorly understood at present. This research work is based on field measurements, observations, analytical work and numerical modelling. A practical approach to estimate risks involved with this type of failure is explained towards the end of the thesis.

1.2 OBJECTIVE OF THE THESIS

The objective of this thesis is to provide new knowledge on floor failure mechanism at the longwall coal mining face. The aim is to differentiate between well known foundation failure of weak floor, and floor failure in strong strata with weak bedding planes, that have not been addressed in the past. Several mechanisms of floor failure proposed in this thesis deviate significantly from the traditional idea that floor failure is connected to floor bearing capacity that can be tested directly by placing heavy loads onto the floor. It is true that very weak floors can fail when loaded from above, however, weak bedding planes within floor strata are often only contributors to floor failure in otherwise strong and competent strata. The progressive nature of longwall mining presents challenging differences between the conventional approach to calculating the safety factors of floor failure and an estimation of actual strata behaviour that may occur as dynamic stress changes take place close to the coal edge at the longwall face. This thesis was
structured to provide the engineer with the tools necessary to evaluate the risk of mining in variable floor strata.

Even though the objective to describe some of the complex and variable floor failure mechanisms has been fulfilled, the author would like to encourage ongoing research in years to come to further advance the knowledge of floor failure at the longwall face.

1.3 ORGANISATION OF THE THESIS

This thesis has been divided into 8 chapters, each representing an important part of the overall floor failure mechanisms that can occur at the longwall face.

Chapter 1 introduces the thesis topic in summary form and outlines the importance of this study. Literature review in Chapter 2 describes up-to-date knowledge of floor failure mechanisms and how they are currently analysed. The author has attempted to discuss much of the relevant literature but it is noted that available literature in floor failure analysis is very limited.

Chapter 3 presents underground measurements and observations of progressive floor failure at and ahead of the longwall face that have been measured in the mining roadway driven towards the operating longwall. Various instruments including sonic extensometry, strain-gauged shear strip instruments and several observation holes were used to measure displacements
of floor strata during the approach of the longwall face. This data forms the basis for the analyses that has been developed within this thesis.

Chapter 4 describes the mechanisms leading to floor failure at the face. This chapter uses the "global approach" to explain how stress develops at a typical longwall face. On the basis of stress regime, primary fracture mechanisms in the mining floor are proposed. These mechanisms are discussed along with underground measurements and the computational numerical model that was formulated to validate results.

Chapter 5 explains how an excessive yield of coal can expand and buckle bedded floor strata despite the floor being strong and competent rock. If the coal-floor interface is strong and a weak bedding plane exists below the floor, coal movement towards the goaf may shear the bedding plane. Pinning action below the powered supports will restrict upper floor movement and buckling can occur. This failure will manifest itself as floor heave ahead of the powered supports, a condition that can seriously affect longwall production.

Chapter 6 presents an analytical model of floor failure mechanism at a longwall face based on the multiple sliding block model. Under certain conditions, lateral and near vertical fracture planes will develop ahead of the face forming stone blocks within the floor. These blocks displace during mining, interact at the fractured surfaces and concentrate large stresses at the floor surface, often resulting in floor failure which, if large enough, seriously disrupt mining operations. The analytical solutions derived for the moving
stone blocks within the floor are supplemented with numerical models (FLAC) that confirm such movement takes place. The stresses generated at floor level are then compared with both the analytical and computational solutions.

Chapter 7 summarises the types of known floor failure mechanisms, explains the methods required to identify them and gives guidelines to assist the geotechnical engineer with the risk assessment of floor failure. Failure mechanisms are based on the overall content of this thesis. An illustrated example of risk assessment is given at the end of the chapter where a step by step procedure identifies possible floor failure mechanisms of various floor types, evaluates level of risk and suggests remedial actions.

Chapter 8 presents conclusions that have been drawn on the basis of this doctoral study. Evaluation of floor failure mechanisms has been unified to form a comprehensive package for the mining industry. The conclusions highlight the benefits of this work, establishes a new approach to risk assessment of floor failure and outlines recommendations for future work to encourage further research in this important field.