CHAPTER 1

1 INTRODUCTION

1.1 PREAMBLE

“The environmental conditions under which coals are deposited are revealed by the stratigraphy of the coal basins and coal beds and by the details of the structure and the physical constitution of the coals themselves” (White, 1925, In: Ross and Ross, 1984, p.12).

The development of new concepts and a need for novel approaches to applying depositional models to the environments of coal formation is becoming increasingly important in the South African coal industry. Coal is a non-renewable energy resource with an increasing degree of difficulty in its discovery and exploitation. There is therefore an increase in the need to understand the sedimentological origin, formation, and depositional environments to be able to understand coal seam characteristics (Galloway and Hobday, 1996).

The present sedimentological investigation focuses on interpreting the depositional systems in a particular region of the Highveld Coalfield of the South African Coalfields, to obtain a better understanding on the role that geological controls play on coal formation and mining hazards. The main objective of this study is to investigate the depositional systems associated with the No. 4 coal seam at New Denmark Colliery and to determine what role these played in controlling the roof conditions associated with the No. 4 seam. The hypothesis is that different sub-environments within the known, overall
fluviodeltaic regime (Cadle, 1995) produce different sedimentary facies, and these in turn determine the nature and characteristics of rocks associated with the coal (Ferm and Horne, 1979). In this way, an understanding of the depositional systems can be used to predict the sediments associated with these systems and their distribution in unmined areas. This should allow targeting of optimum and poor roof regions; whereafter mining methods can be adapted to accommodate the different predicted geological conditions.

1.2. LOCATION

The area of interest is situated in the northern portion of the Karoo Basin (Tankard et al., 1982). The geographic location of the study area and its position relating to the pre-Karoo basin margin is shown in Figure 1.1.

The specific study area is situated at New Denmark Colliery some 180 km south-east of Johannesburg in the Mpumalanga province of South Africa. The New Denmark Colliery lies within the Highveld Coalfield (Jordaan, 1986), south of the Witbank Coalfield, and is situated between the towns of Bethal, Standerton and Greylingstad. The study area covers approximately 70,000 ha (Figure 1.2).

The area is geologically situated in the north-eastern portion of the Karoo Basin, from which it is separated by a pre-Karoo felsite ridge (Le Blanc Smith, 1980). The boundary of the Highveld Coalfield study area is also shown in Figure 1.3.
Figure 1.1. Distribution of the Karoo Supergroup within the Karoo Basin and elsewhere in Southern Africa. The section line X-X’ is shown in Figure 1.5 (modified after Tankard et al., 1982).
Figure 1.2. Locality map of the study area
Figure 1.3. Locality map of the study area within the Highveld Coalfield (modified after Jordaan, 1986).
1.3 OBJECTIVES AND METHODOLOGY

1.3.1 Objectives

This study aims to:

1. Identify depositional systems for the New Denmark region, which will be equally applicable in similar environments and their distribution in unmined areas.

2. Interpret and reconstruct the palaeoenvironments in which the coal seams at New Denmark Colliery study area originated.

3. Interpret the depositional systems that formed the strata associated with No. 4 coal seam, and to identify what role these played in controlling the roof conditions. More specifically, attempt to define and establish the relationship between various depositional environments that cause unstable roof conditions above the No. 4 seam.

4. Determine different trends in the roof above No. 4 seam in relation to the different facies types, as described later in this study.
1.3.2 Methodology

The present study utilizes 1951 borehole logs, covering an area of approximately 70,000 ha, in the northern Highveld Coalfield (Figure 1.4). Data from two mining houses, Anglo Coal Geological Services and Sasol Mining are utilized in this study. These data have been compiled during visits to the New Denmark Colliery and Sasol Mining geology office in Secunda.

The boreholes were drilled over the last sixty years and therefore contain varying descriptions of the lithologies. However, these data are relatively fundamental and provide basic descriptions of all the lithologies and abundant pertinent information needed for the sedimentological analysis.

In addition to the borehole descriptions, field visits were undertaken to New Denmark during drilling operations. During these visits, borehole core was logged, sampled and photographed; all of which are data used in this study.

The data from 900 boreholes was selected on the basis of the best stratigraphical appearances, these data were than computerized applying the Miner 2, and Microstation computer programs. These software programs are used to produce cross-sections, isopach maps of seam thickness and parting thickness. Borehole data covering the study area, selected in a grid fashion, was transformed into a graphic form via the graphic Log program. These were then compiled and used to generate borehole cross-sections and three-dimensional diagrams, thereby providing a better understanding of the depositional origin of the sediments. Vertical and lateral relationships of facies, graphically presented, were formulated, resolving the detailed lithostratigraphy on a sub-regional scale. Computer-generated isopachs were then plotted, and all of this information utilized in interpreting the sedimentary origin for the strata.
Figure 1.4. Borehole location map, illustrating the density of boreholes available for this study, and the data limits.
These interpretations led to constructing a geological model to determine specific characteristics, and to infer changes in strata that pertain to rock type, geometry, bedding type, thickness and therefore roof falls and their possible predictions.

1.4. REGIONAL GEOLOGY

The Karoo Supergroup of the South Africa contains a broad spectrum of Carboniferous to Jurassic strata (Tankard et al., 1982; Smith et al., 1993). The Karoo Supergroup is lithostratigraphically subdivided into the Dwyka Group, Ecca Group and Beaufort Group, succeeded by the Molteno Formation, Elliot Formation, Clarens Formation and Drakensburg Formation (S.A.C.S., 1980). These subdivisions are shown in Table 1.1. This study is primarily concerned with the Vryheid Formation, which contains the coal seams.

The Dwyka Group consists of tillite, diamictites and reworked tillite and shales, overlain by sandstone (Figure 1.5). Large deposits of coal are associated with certain sandstones and shales of the Ecca Group (Haughton, 1969; Cadle et al., 1993; Snyman, 1998). On the basis of lithological and palaeocurrent data, the Ecca Group has been divided into three Formations: The Pietermaritzburg Formation; The Vryheid Formation and the Volksrust Formation. In the New Denmark study area, the major exploitable seam is No. 4 seam, found at an approximate depth of 200m below surface, with an average thickness of ± 2m.

The Beaufort Group overlying the Ecca Group consists predominantly of a sequence of mudstone alternating with sandstone and contains abundant flora and fauna remains (Rubidge, 1995). The regional distribution and ages of the Karoo coal seams are shown in Figure 1.6.
Figure 1.5. North-east South-west cross-section (Figure 1.1.) through the Karoo Basin showing: (A) Distribution of major lithological units, (B) Major depositional systems (modified after Tankard et al., 1982).
Figure 1.6. The development and ages of coal seams in various Karoo Basins in South Africa (modified after Falcon, 1986).
1.5 PREVIOUS WORK

1.5.1 General studies

Early studies on the Karoo Basin lithologies were stratigraphically orientated with lithostratigraphic subdivisions into the Dwyka, Ecca, Beaufort and Stormberg Groups, which were further subdivided (du Toit, 1954). Lithological and to a lesser extent palaeontological criteria have been used to subdivide the Karoo Supergroup.

Studies relating to the Karoo strata were initially of regional extent and there were only few that focused on local areas. The Dwyka Group is named after deposits present along the Dwyka River found in the southern area of the basin. Graham (1931) stated that the term Dwyka “conglomerate” was not satisfactory and suggested the name tillite instead. Du Toit (op. cit.) studied striation directions, reconstructing their influence on the pre-Karoo topography. Du Toit (op. cit) further compiled these data of movement of the ice sheets and of their sources of material. The inferred ice movements are shown in Figure 1.7.

Graham (op. cit) studied the “Ecca Series”. He stated that, the coal measures occur in the Middle Ecca, and are of economic importance to South Africa. Du Toit (1954) also discussed the importance of the stratigraphic position of the Ecca coal, and emphasized the value of the Coal Measures. Hamilton and Cooke (1965), in a study of the Middle Ecca Beds or Coal Measures, described the existence of grits, sandstone, carbonaceous shales and coals, which were, according to Hamilton and Cook (op. cit.), best developed in Kwazulu-Natal, Mpumalanga and the northern Free State.
Figure 1.7. Map showing the inferred ice centers of the Late-Carboniferous ice. The arrows indicate observed glacial striae. A, Namaqualand; B, Griqualand West; C, Northern Province; and D, KwaZulu-Natal ice centers (modified after du Toit, 1954).
Haughton (1969) described the presence of glauconite in the Middle Ecca beds of Southern Mpumalanga and in the Northern Free State, which led Hart (1966) to believe in the existence of marine conditions at that period of time. Haughton (op. cit.) further suggested that the basin or "embayment" received fresh water when Dwyka ice-caps melted during the early Permian which then led to a desalinated gulf, conditions which disabled micro-invertebrate fauna. Tankard et al. (1982) described transgressive flooding episodes over the land surface, excluding residual ridges of basement granite and felsite that protruded above water level as an archipelago chain. Le Blanc Smith (1980) proposed that the initial transgressive medium was fresh water, followed by an upper "marine" destructive phase, when glauconitic sand, ranging from a few centimeters to over 15m and more in thickness, was deposited. Preservation of such thickness implies that the sand was supplied by longshore drift processes, influencing delta morphology and depositional patterns. Early deltas were small, elongate, and coarse-grained, termed fan-delta types (McPherson et al., 1987).

The sediments of the Vryheid Formation were therefore formed by deposition of a variety of fluvial, deltaic, shoreline and transgressive shallow marine depositional systems. Included in these clastic sedimentary strata are South Africa’s most important coal reserves (Snyman, 1998). Following these broad sedimentological investigations, research began to focus on more applied studies. This was partly in response to economic incentives and attempts to solve geological problems encountered at the collieries.

1.5.2 Applied coal studies

One of the first authors who studied the Witbank Coalfield was Wybergh (1922). In one of the earliest works of its kind, he explains the origin and environmental setting of the deposits. Du Toit (1954) recognized some of the
coal characteristics, noting that the coals formed from the *in situ* growth of vegetation. He further noted that the lower sections of the coal seams are "purer" than the upper portions.

On a basinwide scale, tectonic conditions played a role in influencing the thickness of coal seams; the thicker seams occur in stable, intracratonic areas. Cairncross (1979) stated that the earliest developed coals are thicker, and formed during the early, post-glacial period.

A further refinement of the sedimentary environments influencing coal formation was introduced by Le Blanc Smith (1980) who interpreted the large deltas of the Witbank Coalfield as high-constructive and fluvial-dominated. He also described arenaceous sequences forming as deposits of distal sandy braided streams.

Cairncross (1980) described the role of anastomosing fluvial channels in the No. 2 seam at Van Dyks Drift Colliery, and the deleterious effect these have on coal seam distribution and quality. Later Cairncross (1986) also documented the importance of clastic partings in the No. 2 seam at Arnot Colliery leading to splitting of coal, through deposition of sediments by braided or anastomosed fluvial systems. Correlations have also been made between the chemical composition of coal and its palaeoenvironmental origin (Cadle et al., 1993). Other investigations that have successfully applied sedimentological studies to obtain better understanding of Karoo coals include Holland *et al.* (1989), Hobday (1987), Cairncross and Cadle (1988a, b), and Falcon (1989), the latter study focusing particularly on the sedimentological controls on micro- and macro-factors affecting coal petrography, related to the depositional origin of the peat. Similar detailed sedimentological studies were carried out on the coal deposits in northern Kwa Zulu-Natal (Christie, 1988; Roberts, 1986) and these are summarized in Tavener-Smith *et al.* (1988). Cadle (1982) and Winter (1985) in their descriptions of the Highveld Coalfield, demonstrated that deltaic and fluviodeltaic deposits dominate in the coal-
bearing Vryheid Formation. Cadle (1995) referred to the importance of petrographic, palynological, geochemical and proximate and ultimate data analyses of the seam to be able to successfully understand and provide a stratigraphic framework and create models of peat formation of the various areas of the coalfield.

Most applied sedimentological studies in the Highveld Coalfield have been based primarily on borehole data. Winter (1985) related No. 4 seam coal qualities to fluvial palaeochannels. The coal seams situated close to these palaeochannels are generally low-quality coals and Winter (op. cit.), describes sedimentological details of the channels within the No. 4 seams of the Highveld Coalfield. Due to lateral stacking of channel-fill sequences, seam splitting occurs, and extraneous ash values are high.