CHAPTER 5

5 GEOLOGICAL FACTORS AFFECTING No. 4 COAL SEAM ROOF CONDITIONS

5.1 INTRODUCTION

The energy situation with which the world is confronted today is such that, within the next one to two decades, there are likely to be very substantial changes, mainly in the direction of demand outstripping supply (Shepherd and Gale, 1982). The prospective energy situation calls for very vigorous and careful planning and the research program which is going to be required in the South African coal industry in order to meet this developing situation of a possible energy shortage, must be conducted in different ways to maximize coal extraction and utilization.

These increasing energy needs have prompted detailed examinations of existing and potential coalfields in South Africa. Evaluations of coal resources in the Karoo Basin have concentrated on mapping individual coal beds and/or zones. Detailed studies of Vryheid Formation coal-bearing rocks in support of this type of resource evaluation indicate that environments of coal deposition play a major role in controlling coal thickness, lateral extent, nature of the floor and roof rocks and potential mineability (Le Blanc Smith, 1979). Therefore, the purpose of this chapter is to present the various depositional settings and to examine the way in which these palaeoenvironments influenced No. 4 coal seam roof conditions.

The processes associated with peat formation, together with the physical and chemical properties of the non-coal strata and coal at different stages of rank
advance, are responsible for the occurrence of the various geological features in and around coal seams. A full understanding of these features needs to be clearly recognized and understood. Once these factors are understood in a particular area it is possible to provide a better framework on which to base further exploration or mine planning operations (Galloway and Hobday, 1996).

During recent years, involvement of geologists in operational aspects of the coal industry rapidly increased, which led to applications of depositional models for solving problems with respect to roof stability (Bell and Jermy, 2002). Once a depositional model has been established for a study area, it can be used to predict the distribution of coal seams in the region, and therefore improve the understanding of the areas most suitable for further exploration (Miall, 2000). Once the factors that control the mode of formation in a particular area are understood, it may be possible to predict quality and thickness variations in an individual seam (Horne et al., 1978; Cairncross, 1986) over colliery boundaries, as well as variations in the nature of the floor and roof strata. This knowledge is invaluable to mine planning operations.

Procedures for developing these models include direct observations to assemble a three-dimensional reconstruction of the coal seam and surrounding rock bodies, establishing a relationship between the geological parameters and mining conditions, and comparing this data with modern depositional systems. These data would enable the geologist to make predictions about the characteristics of the coal and surrounding rock bodies.

The contact between coal and its overlying strata is illustrated in Figure 5.1. In some cases the coal and its roof rock have an erosional contact caused by the intervening strata (Diessel, 1992) as illustrated in Figure 5.2.
Figure 5.1 Borehole core at the drilling site in the north-eastern part of the study area at New Denmark. The borehole core includes a complete sequence. See Figures 4.2-4.5 for the lithostratigraphic classification of this sequence. Note core is in 10m intervals.
Figure 5.2. Grit lenses within carbonaceous siltstone. Note erosive contacts.
5.2 COAL-PRODUCING SEDIMENTARY ENVIRONMENTS AND THEIR RELATIONSHIP WITH ROOF STRATA

A summary of the depositional controls on the shape of coal bodies may be used to guide the design and implementation of a broad-scale exploration program (Ward, 1984). However, of vital significance are more detailed studies associated with the planning and operation of coal mines (Horne et al., 1978). The use of paleoenvironmental studies is important in determining hazardous roof conditions. Particular hazards occur more in roof rocks deposited in one paleoenvironment than another. When that environment has been established in advance of mining, precautions can be taken during the mine planning phase. Depositional environments of coal play a major role in controlling coal thickness, lateral continuity, potential minability and type of floor and roof rocks (Flores, 1978).

Roof strata stability varies widely due to the interrelations of rock types, syn-depositional structures, early post depositional compaction traits, and later tectonic features (Ferm and Melton, 1975). Roof stability is governed by the lithology of rocks and their structural defects as Jeremic (1985) pointed out. He further describes stability of the roof as an increasingly important element in mining.
5.3 FACIES ASSEMBLAGES ABOVE No. 4 COAL SEAM

5.3.1 Fluvial sequence

DESCRIPTION

Conglomerates separate the No. 4 and No. 4 A seams at New Denmark Colliery. These rudites have various angular and erosional contacts with the underlying No. 4 seam coal roof. In some cases, the principal bedding planes of both lithosomes have similar attitudes irrespective of the occurrence of irregular erosion scours at the conglomerate base (Figure 5.3). On the other hand, an angular discordance exists between the bedding planes of the two units, and there are many transitions between two types. The New Denmark study area conglomerate mostly consists of 10-30cm thick layers of granule to pebble conglomerate facies alternating with up to 25m thick beds of coarse to pebbly sandstone facies. Since peat accumulation appears to be frequently terminated by stream avulsion, it is not uncommon to find erosional bases of fluvial sandstones and conglomerates forming the immediate roof of No. 4 coal seam (Figures 5.4 and 5.5).

INTERPRETATION

Fluvial deposits in general show the greatest range of textural variability, in particular the sediment sorting which is mostly poor (Galloway and Hobday, 1996). Coal seams associated with fluvial channel deposits are commonly oriented parallel to depositional dip, and because of the less regular course followed by the river channels, the seams may vary greatly in thickness over
Figure 5.3. West-east cross-section above the No. 4 coal seam illustrating the coarse-grained fluvial channel deposits above No. 4 seam.
Figure 5.4. Contact between the roof of No. 4 coal seam and overlying pebbly sandstone. Note bar-scale in 10cm intervals.
Figure 5.5. Fluvial depositional sequences above No. 4 coal seam. Note bar-scale in 10cm intervals.
short distances, and seam splits may be developed in association with the contemporaneous levee bank deposits (Cairncross, 1980; Ward, 1984; Winter, 1985). Depending on the nature of the fluvial regime (anastomosing, braided, meandering) the fluvial sediments generally have point bar or channel fill deposits which occur in a variety of spatial relationships with associated coal seams (Diessel, 1992). It is also common to find postdepositional fluvial deposits cutting through several metres of sediments, riding on top of a seam. However, even without loss of coal, mining conditions may be difficult in the areas along the erosional contacts (Figure 5.6). It is therefore advantageous for the purpose of mine planning to have prior knowledge of coal contacts, which might adversely affect the seam roof conditions during coal extraction.

5.3.2 Deltaic sequence

DESCRIPTION

Deltaic deposits occur between the No. 2 and 3 and No. 4 and 5 seams. The most widespread and common components of the deltaic successions in the study area are interbedded fine-grained sandstone and siltstone, containing coal spar, which occur in medium- to small scale coarsening-upward sequences. Coarsening-upward sequences are most characteristic in the eastern half of the coalfield. Medium-grained sandstone is also present in this interval but occurs as subordinate bodies that are flanked by coarsening-upward successions.
Figure 5.6. Erosional contact of fluvial sandstone and conglomerates forming the immediate roof of No. 4 coal seam. Note the coal-spar rip-up clasts approximately 25cm and 8m from the base of the succession. Note bar-scale in 10cm intervals.
INTERPRETATION

Another equally important coal-forming environment, apart from fluvial associations, is in delta complexes. More specifically, the upper delta plain, (Ferm, 1976) and the transitional lower delta plain (Horne et al., 1978) are often recognized as the most important coal producing environments. Because of the differential interplay of fluvial input, wave and tidal action, sediment dispersal, tectonic settings and a variety of other factors, deltas are very complex sediment bodies (Klein, 1975). The resultant coal seams that developed in the upper delta plain usually tend to be continuous along the direction of depositional dip, but can occur parallel to depositional strike, with coal being replaced in some places by interdistributary bay-fill material (Ward, 1984). An example of coarsening-upward delta sediments shows lithologies that grade from siltstone upward through sandstone.

Bioturbation found within shales, siltstones and sandy siltstones appreciably lowers the strength of the rock. The bedding surface contacts between sandstone and siltstone acts as planes of weakness causing separation of sandstone-siltstone producing roof falls. When less compactable rocks such as sandstone are surrounded by more compactable types such as shales and siltstones, differential compactional features occur. Superimposed on these characteristics are later tectonic structures such as jointing and fracturing.

5.4 No. 4 COAL SEAM ROOF LITHOLOGIES AND TREND ANALYSIS

Geological cross-sections were constructed to illustrate the lateral distribution of the succession above the No. 4 coal seam. Figure 5.7 shows the locations of these sections, which are illustrated in Figures 5.8-5.12. The sections where
Figure 5.7. Locality map showing the positions of cross-sections (Figures 5.8-5.12) used to illustrate the details of the facies assemblages in the roof above No. 4 seam.
Figure 5.8. West-east cross-section A-B above the No. 4 coal seam depositional sequence. See Figure 5.7 for the location of cross-section.
Figure 5.9. West-east cross-section C-D above the No. 4 coal seam depositional sequence. See Figure 5.7 for the location of cross-section.
Figure 5.10. West-east cross-section E-F above the No. 4 coal seam depositional sequence. See Figure 5.7 for the location of cross-section.
Figure 5.11. North-south cross-section G-H above the No. 4 coal seam depositional sequence. See Figure 5.7 for the location of cross-section.
Figure 5.12. Southwest-northeast cross-section I-J above the No. 4 coal seam depositional sequence. See Figure 5.7 for the location of cross-section.
hung on a marker horizon, the No. 4 coal seam, as this represents a time-line during peat accumulation. These cross-sections have been generated to define areas in which differential compaction features are likely to occur, more importantly, to define areas exhibiting an adverse ratio of strong roof to weak roof. Cross-sections throughout the study area show that the thickness of the sandstone-siltstone unit ranges up to 12m.

A west-east cross-section (Figure 5.8) through the study area shows the thickening of the conglomerate facies towards the east (Figure 5.12). This section illustrates the depositional sequence setting after the formation of the No. 4 coal seam. It is based on data related to lithological and sediment-thickness variations. These data suggest that, the conglomerate facies are thickening towards the eastern part of the study area, and the sediments are also thickening southward (Figure 5.11). The sandstone grain sizes are predominantly medium- to coarse-grained. Grain size diminishes upward (Figure 4.5) within these sandstones, and abundant pebble lags and coal spars are present in the lower part. The interval of sedimentation that includes the major No. 4 coal seam also contains coal spars separated by thin coarsening-upward sequences, rock types indicative of delta crevasses-splays. These sequences show a coarsening-upward pattern, and are capped by the transgressive marine glauconitic sandstone (Figure 4.4). The marine glauconitic-bearing medium-grained sandstone, is one of the most widespread marker beds in the New Denmark study area, as well as in the Highveld Coalfield area. The primary conclusion drawn from the data is that differential subsidence, noted in the regional analysis, is a major controlling factor at New Denmark. This is particularly evident in comparing the coarse sandstone dominated fining-upward sequences, the thickness of which is of prime importance in differentiating coarse-grained fluvial-plain deposits in the study area. The total thickness of the conglomerate facies in the north is greater than the south, but except where an overlying sandstone has incised into an underlying one, the thickness of individual bodies, in the north and south are with a maximum of about 20m in both areas.
The formation of the No. 4 seam peat was periodically interrupted by sedimentation in both widespread and local environments; in general the former occur where the marine environment was present. In deltaic areas, sedimentation patterns are complicated by vagaries in the size and number of distributaries and by delta-switching. Because the peat formation was so disrupted, the lateral continuity of coal seams together with the roof rocks, is equally interrupted, especially when associated with the more marine sequences. Furthermore, the fluvially associated coals are erratically split. An example of the latter is illustrated in Figure 4.5. This figure illustrates that sandstone is splitting No. 4 coal seam, into No. 4 A in the western part of the study area. Conolly and Ferm (1971) describe such seams from the Sydney Basin, as being typical of those formed in a fluvial backswamp environment. Many hazardous depositional conditions are associated with palaeochannel fills. A typical channel-fill sequence may erode and sometimes replace the coal; cause coal splitting, coal thickening, mud slips, slickensided planes, and distorted bedding or slump deposits. These cause roof conditions that promote mining hazards. An isopach map of coal thickness was compiled for the No. 4 coal seam. This map shows that this coal seam thickens towards the west and north-west of the study area (Figure 5.13).

Difficulties produced in underground coal mines by unfavourable strata must be taken into account in geological assessments at an early stage of an exploration program. Changes in roof rock structure and lithology, vertically and laterally, may be encountered. Many structural and lithological aspects of roof rocks are interrelated in a complex manner making it more difficult to anticipate where problem areas will be encountered as mining progresses. An attempt was made to study the lithological behaviour of the roof by compiling different maps, enabling the possibility to detect areas prone to roof falls.
Figure 5.13. Isopach map of the No. 4 coal seam in the New Denmark study area.
Maps have been prepared by considering average 20m thick strata above the roof of the No. 4 coal seam, because that is considered the maximum which the rocks no longer play a role in roof conditions which can be related to roof falls. Examination of the mine workings and drill records indicates that the No. 4 coal seam in the study area is overlain by a thick, up to 25m, massive to bedded sandstone, and conglomerate facies. Figure 5.14 illustrates that the conglomerate facies are thickest in the east of the study area and in a semi-linear zone trending east/north-east to west/south-west with a limb also striking south (Figure 5.14). This isopach map was generated to define areas in which differential features are likely to occur and more importantly, to define areas of strong roof to weak roof. The strength profile of the roof will depend primarily on the lithology and planes of weakness of the rock strata. The thickness of sandstone-siltstone (Figure 5.15) shows the unit directly below the glauconite marker, approximately 20m above No. 4 coal seam roof. This sandstone-siltstone thickens from east to south-southwest. The thickest sandstone-siltstone is found in the north-east, showing that the palaeochannels that eroded into the underlying strata, were later filled by the younger sediments. The differential compaction along the channel bodies weakened the roof. The location of potential and known roof falls in the area, are mapped and plotted on an underground plan, which is then overlain with conglomerate facies plan, to be able to identify relationship between them, if any (Figure 5.16). However, some of the roof falls could not be mapped since all these areas are not accessible due to hazardous roof conditions. Figure 5.16 shows the mine hazard plan, illustrating that roof falls are mostly confined within the north-eastern of the study area.

The sedimentary interval mapped out is up to 10m thick (Figure 5.15). The isopach map of this sandstone-siltstone interval illustrates a general thickening of the sequence towards the south. The isopach of this deltaic sequence, taking into account the thinning of the sediment against the basement high in the west, supports a lobate geometry. As expected, the greatest variation of facies occurs in the delta settings.
Figure 5.14. Isopach of the conglomerate facies directly above the No. 4 coal seam depositional sequence. The facies thins towards the west and thickens eastwards.
Figure 5.15. Isopach of sandstone-siltstone directly below the glauconite stratigraphic marker.
Figure 5.16. The mine hazard plan overlying conglomerate facies directly above No. 4 seam.
The locus of sand deposition periodically changed as delta elongation caused avulsion and this accounts for the irregular distribution of many of the channel sands tone bodies. Because the data has mainly been obtained from drill holes at 1km or more spacing, the pattern of the distributary channel network is almost certainly even more complex than the present data indicates. However the detailed anatomy of the delta margin deposits does not appear to exert a major control on the distribution, properties or thickness of the No. 4 coal seam, since the latter have accumulated on the laterally more extensive upper delta plain environments. In addition, deltaic environments may be strongly influenced by a sea-level change (Ross and Ross, 1984). However, Oti and Postma (1995) stated that the underlying fine-grained strata locally influence peat deposition and cause minor seam splitting but, generally, coal maintains a uniform thickness and character over underlying lithologies ranging from lacustrine clay to channel sandstone. Distributary channel deposits occurring between No. 4 and No. 4 A seams create mining problems, ranging from losses of production, roof failures and unexpected loss of an economic coal due to split seams. Clearly, it is necessary to map these features as early as possible, during exploration stages.
5.5 FACTORS CONTROLLING No. 4 COAL SEAM ROOF CONDITIONS

Roof falls attributed to geological factors in underground coal mines include both lithological and structural discontinuities. Therefore, roof conditions could be predicted ahead of mining if this data is available. An outline of the facies recognized in the study area associated with the economic No. 4 coal seam is given in Table 5.1. This table provides a summary of underground behaviour of the different facies. It must be taken into consideration that a clear distinction between good and poor strata is difficult to define and it may vary depending on different mining methodologies and technologies. Weak strata could be identified by the presence of slump deposits and channel scours. Weak to reasonable roof strata is associated with pebbly sandstone, cross-bedded sandstone, sandstone with shale and siltstone streaks, or interbedded sandstone-siltstone and sandstone-shale and sandstone and conglomerate. Stable roof conditions are generally found in areas with massive grey sandstone.

Coarsening-upward rock sequences generally promote competent roof conditions. Bell and Jermy (2002) indicated that rocks which occur in a sequence which rapidly coarsens-upward may provide competent roof since the strength of the rock is increasing upwards. As a sequence changes vertically from silty and shaly to more sand-rich rock types, the strength of rock increases. The lower layers, however, must be bound together by roof bolts. Stratigraphically higher layers are usually capable of supporting themselves and are not as strongly effected by stress, as is the immediate roof, approximately 1.5m above the seam. Bell and Jermy op. cit. further stated that a sequence that fines-upward, for example, from a thin sandstone at the base, to an overlying shale incorporated with thin coal, can prove difficult to control. The reason being that the bedding plane contact between the argillite above and sandstone below, acts as a plane of detachment. Fining-upward sequences can therefore be potentially dangerous, depending on the
<table>
<thead>
<tr>
<th>Facies</th>
<th>Description</th>
<th>Generalization behaviour of strata underground</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Carbonaceous mudrock</td>
<td>Very poor roof and floor strata due to low tensile strength and poor durability; deteriorates rapidly upon exposure.</td>
</tr>
<tr>
<td>2</td>
<td>Lenticular-bedded mudrock, micaceous and laminated</td>
<td>Rock falls common and floor heave occurs when depth of mining exceeds 150m.</td>
</tr>
<tr>
<td>3</td>
<td>Alternating layers of mudrock and sandstone</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Flaser-bedded sandstone</td>
<td>Reasonable roof strata which deteriorates upon exposure, giving rise to spalling from the roof.</td>
</tr>
<tr>
<td>5</td>
<td>Ripple cross-laminated fine-grained sandstone</td>
<td>Reasonable roof strata, although localized roof falls do occur due to parting along silt drapes. Good durability.</td>
</tr>
<tr>
<td>6</td>
<td>Ripple cross-laminated fine-grained sandstone with grit bands</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Fine-grained feldspathic sandstone</td>
<td>Very competent floor and roof strata due to low porosity and high tensile strength.</td>
</tr>
<tr>
<td>8</td>
<td>Cross-laminated fine-grained feldspathic sandstone</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Medium-grained feldspathic sandstone</td>
<td>Good roof and floor with fairly high tensile strengths. Sometimes creates problems due to poor goafing ability in longwall areas.</td>
</tr>
<tr>
<td>10</td>
<td>Cross-laminated medium-grained feldspathic sandstone</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Coarse-grained feldspathic sandstone</td>
<td>Good roof and floor strata. May disintegrate under prolonged saturation giving rise to stability problems.</td>
</tr>
<tr>
<td>12</td>
<td>Cross-laminated coarse-grained feldspathic sandstone</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Bioturbated siltstone or sandstone</td>
<td>Deteriorates rapidly upon exposure and saturation to give roof and floor instability.</td>
</tr>
<tr>
<td>14</td>
<td>Fine-grained feldspathic sandstone with carbonaceous drape and slump structures</td>
<td>Potentially very poor roof conditions. Very unpredictable.</td>
</tr>
<tr>
<td>15</td>
<td>Carbonaceous silty sandstone</td>
<td>No information available.</td>
</tr>
<tr>
<td>16</td>
<td>Coal, mixed dull and bright</td>
<td>Generally mined, but when left in roof or floor are more stable than facies 1 to 3.</td>
</tr>
<tr>
<td>17</td>
<td>Mixed coal and mudrock</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Carbonaceous mudrock (associated with coal seams)</td>
<td></td>
</tr>
</tbody>
</table>

Table 5.1 Sedimentary facies and summary of their underground behaviour as described by Bell and Jermy (2002) from the Majuba Colliery. The present study revealed the existence of these facies in the New Denmark study area.
sequence and kind of rock type involved. If an approximately 4.5m thick sequence of fining-upward sandstone to siltstone with coal spar rider seams at the top forms the roof, it will be extremely difficult to support, particularly if the sandstone is thin, less than 1.5m or is discontinuous. This would suggest that problems of roof instability could arise and the entire sequence will probably break along the sandstone-siltstone contact and fall up to the rider seam.

5.5.1 Rider seam

A rider seam is typically a thin, discontinuous coalbed above the seam being mined (Horne et al., 1978). Rider coals are developed when natural stream levees are temporarily breached, and sediment is then distributed into the adjacent swamp. When the flood waters abate, swamps become re-established, colonizing the sediment. The resultant peat forms a thin and laterally discontinuous rider coal (Kane et al., 1993) separated from the underlying main coal by the flood sediments. When the sedimentary rock interval between the rider seam and the main coalbed thins, the rider forms a plane of weakness, which can result in massive roof falls. A rider seam is illustrated in Figure 5.17 and is developed throughout much of the north-east part of the study area, above the No. 4 coal seam. This area may be referred to as the “rider seam area”. The rider seam is up to 15cm thick, and is located within the massive to pebbly fluvially-associated sandstone facies roof. Where the rider seam is present in the immediate 0.2-1.5m of roof strata, its presence definitely facilitates roof collapses.
Figure 5.17. (A) Rider coal above No. 4 coal seam, within the massive to pebbly sandstone. (B) Note also detailed view of the rider coal. Noting these features in core can aid in planning of appropriate roof support.
5.5.2 Palaeochannel deposits

Palaeochannel deposits are linear trough-based masses usually composed of coarse-grained, cross-bedded sandstone. In some places, such as at the Rietspruit Colliery (Winter, 1985) palaeochannels incise into the underlying and adjacent peat beds and get filled with sand and become abandoned (Kane et al., 1993). Pebble lag deposits, particularly containing micaceous siltstone and coal fragments, cause the main roof problem at New Denmark Colliery. They occur at or near the base of the palaeochannel fills and constantly weaken the roof. The palaeochannels usually originate in the upper delta-plain, fluvial or transitional lower delta-plain environment (Horne et al., 1978). When mining occurs beneath the palaeochannel boundary, the incidence of roof falls increases. The presence of palaeochannels can be seen in a detailed cross-section illustrated in Figure 4.4 above the No. 4 coal seam. These are bed-load fluvial deposits above No. 4 coal seam and consequently provide potentially dangerous roof conditions. In addition, comparisons of the No. 4 seam isopach map (Figure 5.13) with the overlying distribution of the palaeochannel pebbly sandstone (Figure 5.14) shows interesting and definite relationships. The thinnest coal is in the east and southeast (Figure 5.13), and this coincides very closely with the thickest palaeochannel pebbly sandstone. This inverse relationship is caused by channel scouring and thinning of the peats. In addition, extra sediment loading of the thick sand body would have compressed and thinned the peat below. Furthermore, a “linear” zone of relatively thin No. 4 seam (Figure 5.13, 1-1.5m thick) strikes northeast-southwest through the north/central part of the property. This also may be related to the relatively thicker palaeochannel fill above (Figure 5.14).
5.5.3 Pinchouts

Pinchouts are caused by the coincidence of the upper and lower bedding surfaces laterally, causing the narrowing of beds in a horizontal direction. This type of bedding is recognized in all parts of the study area and is illustrated in Figures 4.2 and 4.4 where the pebbly sandstone above the No. 4 coal seam pinches out. Moebus and Ellenberger (1982) pointed out that pinchouts are commonly found along the boundaries of channel fill sequences in a zone that can be associated with an increased possibility of roof falls. These unstable roof conditions are caused by an interfingering of the sides of channel sandstones with the laterally adjacent equivalent flood plain facies, such as mudstones and siltstones. Slabs of these interbedded rocks tend to collapse from unsupported roofs (Cairncross, 1980).

5.5.4 Slickensides

Slickensides are commonly developed adjacent to the flanks of palaeochannel sandstone (Cairncross, 1980). Where slump blocks appear together with slicked surfaces, severe roof problems can be anticipated. Channel-bank slump blocks are developed on the cutbank side of laterally migrating channels, most common in the upper delta fluvial-plain and transitional lower delta-plain environment (Horne et al., 1978). Slickensides are, perhaps, the most dangerous of all coal mine roof features, and the most common ones. Because of the numerous slickensided surfaces and the size of the blocks, severe roof problems are anticipated in the study area wherever these slumps may be encountered. Slickensided surfaces also originate by differential compaction, where claystone or siltstone drapes over more competent sandstone. With additional movements such as faulting or differential compaction, roof falls could develop due to slickensided surfaces in the study
area. When they are present, the danger of roof falls is perhaps confined to instances where coal is left in the roof and slickensided planes also occur. In this situation when the slickensided surfaces and wet roof cracks appear together, may result in unstable ground, promoting the fall of roof coal.

5.5.5 Splay deposits

The sediments for splays originated from flood waters that pierced the banks of distributary channels. Repeated episodes of flooding produce interbedded sequences of thin layers of micaceous sandstone and shales. These can be up to 9m thick and have a sheet-like or lenticular appearance. Most are coarsening-upward. Limited cohesion between sandstone and shale, which is further decreased by plant remains or thin carbonaceous layers on the bedding planes, leads to a further contribution to roof instability and hazardous zones within a mine (Moebs and Ellenberger, 1982). Following crevasse-splay episodes the swamp becomes re-established and rider coals can develop over the splay deposits (Horne et al., 1978). Splay deposits of interbedded sandstone, siltstone and mudstone are recognized in the western part of the study area. The sandstone is of the same composition as that in the main palaeochannels in the study area, but is often restricted in thickness, forming thin sandstone sheets. The sandstone sheets are separated in a vertical sequence by thin siltstone and mudstone laminations. This type of bedding can create rock falls promulgated along bedding plane surfaces.