GEOLOGY, MINING CONDITIONS AND RESOURCE POTENTIAL OF THE WELLINGTON COAL BED, GEORGIA BASIN* (92F/1; 92G/4)

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INTRODUCTION

This report presents initial results of a geological study of the Wellington coal bed and its bounding strata, based on surface and underground mapping, and examination of mine plans and borehole records. It documents the stratigraphy and sedimentology of the Wellington coal, with the intent of identifying and ultimately reducing mining hazards. This project is being done under the auspices of the Ministry of Energy, Mines and Petroleum Geoscience Research Grant program, and forms part of a broader study of the coal resources of eastern Vancouver Island, which is being undertaken by officers and contract staff of the Ministry.

The Wellington coal bed has been extensively worked in the western portion of the Nanaimo coalfield, commencing with its discovery at Harewood in 1864 and continuing for over 120 years, culminating in the opening of a modern colliery at Wolf Mountain in 1984. While mining of the Wellington coal is presently suspended awaiting an improvement in coal markets, ongoing geological studies have outlined several prospective sites for new mines.

EXTENT OF AVAILABLE DATA

Summaries of the geology of the Nanaimo coalfield have been published by the federal and provincial geological surveys (Clapp, 1914; Buckham, 1947a and b; Muller and Atchison, 1971; Bickford and Kenyon, 1988). More detailed reports on specific properties are contained in the coal assessment report files of the Ministry, and in the collections of the Provincial Archives of British Columbia.

Geological records of 158 old boreholes are held by the Provincial Archives. Most of these holes were drilled with primitive diamond-coring tools, resulting in poor core recovery by modern standards. The very earliest boreholes were drilled with churn drills or cable-tool equipment and have relatively more complete records, perhaps as a result of their slower rate of penetration. Between 1980 and 1982, an additional 15 air-rotary boreholes were drilled by oil and mining companies during a brief resurgence of exploration activity. Two wildcat gas tests were drilled by BP Canada Inc. in 1986 (Harmac c-36-F and Yellow Point d-84-C, both in 92G/4).

These wells penetrated the horizon of the Wellington seam but did not encounter coal, demonstrating the coal bed does not extend uniformly into the deeper areas of Georgia Basin. Most of the holes drilled since 1980 have downhole geophysical logs, which are useful for stratigraphic correlation.

Abandonment plans of the larger collieries are preserved in the files of the Inspection and Engineering Branch of the Ministry of Energy, Mines and Petroleum Resources. These plans are of value as they often contain spot measurements of the worked sections. The most detailed and recent mapping has been at Wolf Mountain colliery, where over 200 sections were measured by the author within a 7-hectare area (Bickford, 1987).

Surface geological mapping is less rewarding, owing to the scarcity of coal outcrops. Most of the natural exposures reported by Clapp (1914) have since been obliterated either by mining or by housing development. The roof and floor of the coal are more frequently exposed however, allowing the position and structural configuration of the coal bed to be fairly closely established.

GEOLOGICAL SETTING

The Wellington coal bed crops out along the northwestern erosional margin of the Nanaimo sub-basin of Georgia Basin, near the city of Nanaimo. It lies near the base of the Extension Formation, which is of early Campanian age based on ammonite and molluscan faunal zonation. A geological sketch map is presented as Figure 4-3-1 which depicts the extent of thrusting and folding of the coal bed, which is presumed to be the result of convergent plate motions along the Pacific margin of North America.

STRATIGRAPHIC FRAMEWORK

The stratigraphy of the coal-bearing portions of the Nanaimo Group has recently been revised (Bickford and Kenyon, 1988), taking into account the concentration of coals in comparatively thin units within the sedimentary pile. The Extension Formation, as first proposed by Clapp (1912), has been subdivided into two members: the upper and dominantly conglomeratic Millstream member and the lower, fine-grained Northfield member. Figures 4-3-2 and 4-3-3 depict the relationships between the two members and their bounding strata in the northern and central portions of the Nanaimo coalfield.

The Millstream member consists mainly of quartz-chert-volcanic conglomerate which coarsens from small pebbles in the north at Departure Bay, to cobbles in the south along the Nanaimo River. Millstream conglomerates contain minor

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British Columbia Ministry of Energy, Mines and Petroleum Resources, Geological Fieldwork, 1988, Paper 1989-1.

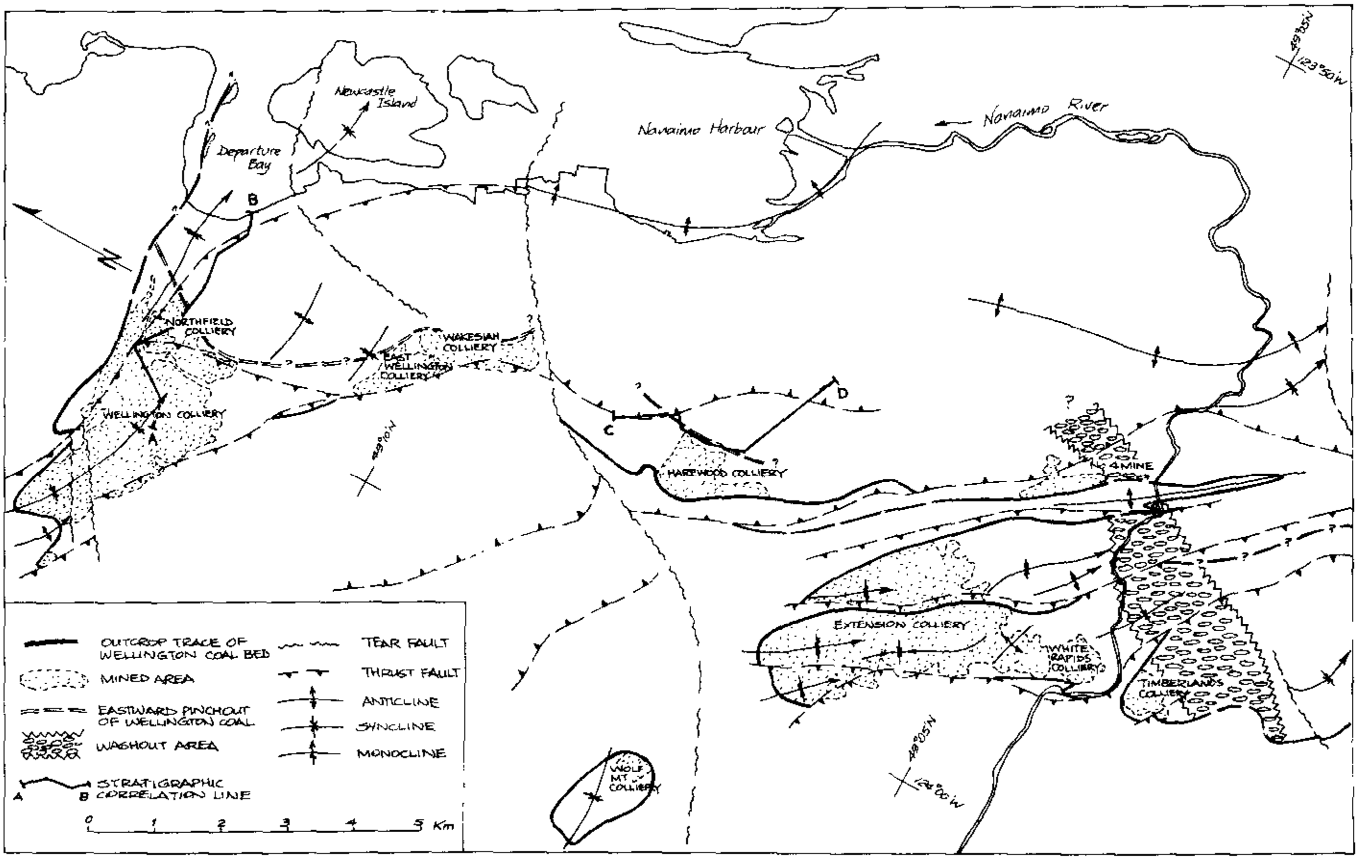

Figure 4-3-1. Geological sketch map of the Wellington coal bed, Nanaimo coalfield.

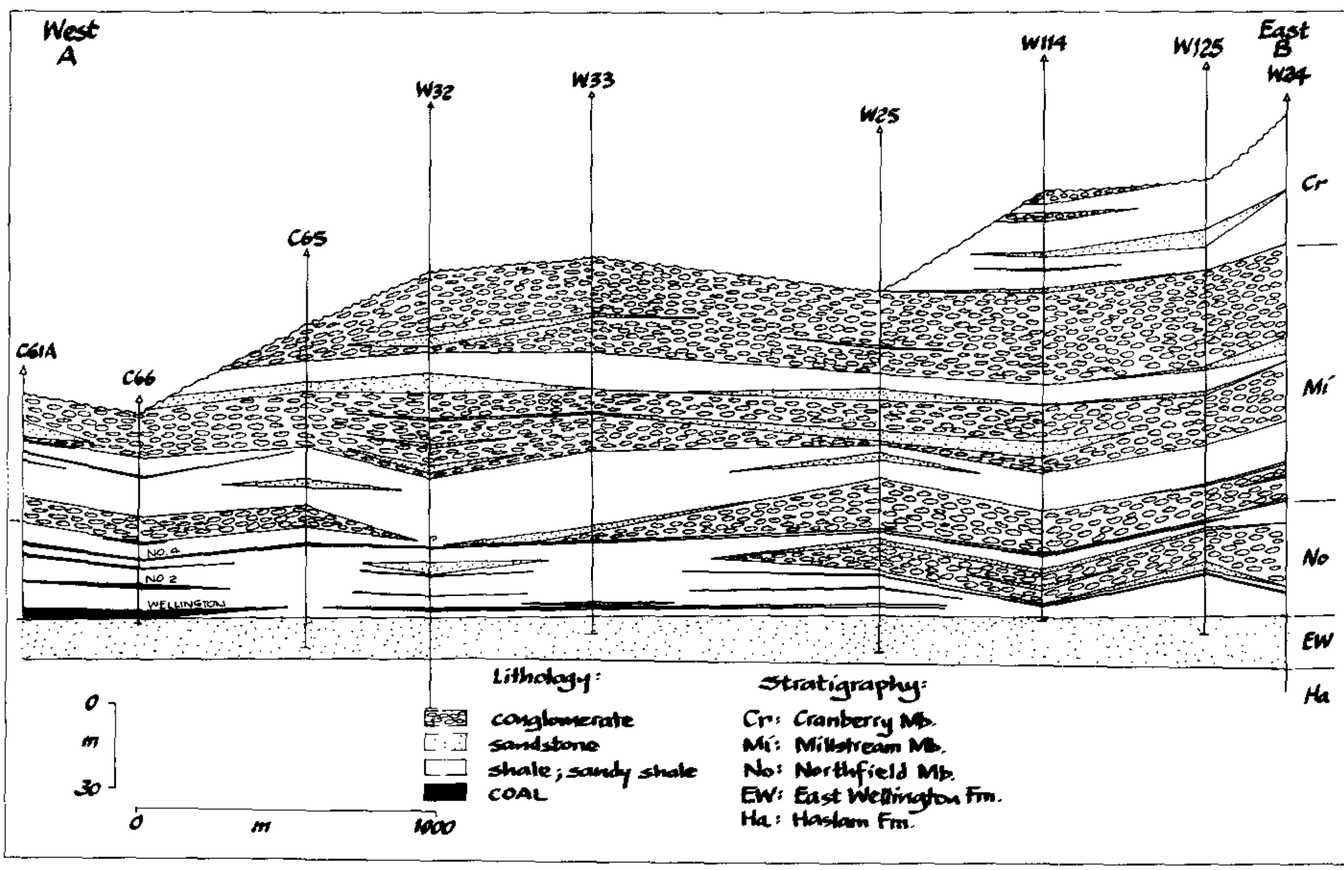

Figure 4-3-2. Stratigraphic section A-B, Wellington coal bed and associated strata, Northfield area.

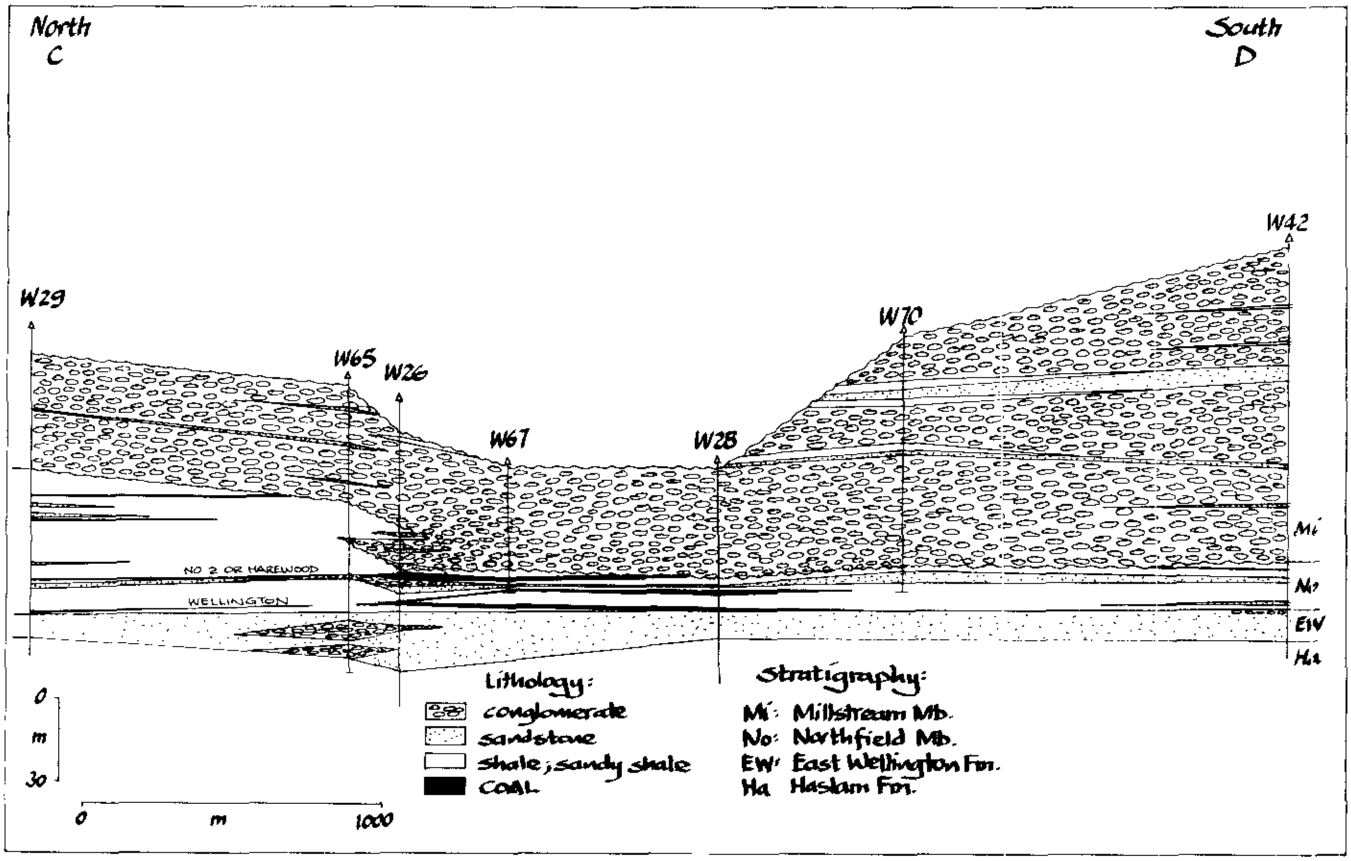

Figure 4-3-3. Stratigraphic section C-D, Wellington coal bed and associated strata, Northfield area.

amounts of a distinctive red hematitic chert or jasper (Clapp, 1914), which appears to have been derived from the Paleozoic rocks of the Sicker Group. Lenses of cherty sandstone and greenish grey siltstone are locally present. The Millstream member is 120 to 150 metres thick along its western outcrop. Isolated deep boreholes show this unit thins eastward into Georgia Basin.

In the southwestern part of the coalfield, near Extension and Wolf Mountain collieries, the Millstream conglomerates are in erosional contact with the underlying Northfield coal measures. In most cases, this contact is expressed merely as a scour surface with minimal vertical relief, but to the south of Extension and Timberlands collieries, the contact takes the form of a washout which has substantially or completely replaced the Northfield member. This washout effectively forms the southeastern limit of known mineable Wellington coal. The onset of the washout is rapid; in Timberlands colliery it cuts down 3 metres in a distance of 30 metres and thus completely takes out the Wellington seam together with its immediate siltstone roof. Beyond the washout, isolated occurrences of coal of potentially mineable thickness have been found in adits and boreholes, but their correlation with the Wellington coal bed has not been conclusively demonstrated.

At least three thin coal beds have been encountered locally by boreholes through the Millstream member. Other than at Wolf Mountain, these coals do not consistently attain a mineable thickness and they cannot be readily mapped (Clapp, 1914). At Wolf Mountain, the Millstream coals have been found to contain numerous partings of black, coaly mudstone, resulting in very high raw ash contents. They are therefore not regarded as mineable (Perry, 1982).

The Northfield member consists mainly of brown and grey mudstone and siltstone (the "sandy shale" of old drilling records). In the northeastern part of the coalfield, near Departure Bay, an eastward-thickening tongue of conglomerate up to 25 metres thick occurs in the middle of the member. The thickness of the Northfield member ranges from 10 metres in the south to 45 metres at Wellington colliery; some of the thickness variation is due to scouring by the overlying Millstream conglomerates, while an abrupt thickening near Harewood colliery (as shown on Figure 4-3-2) appears to be due to lateral intertonguing of the Millstream and Northfield members.

Several coals are present within the Northfield member, of which the thickest is the Wellington coal bed, which lies at the base of the member. Thinner coals overlie the Wellington seam, as shown on Figures 4-3-2 and 4-3-3. Closely spaced underground boreholes in Northfield colliery have disclosed these upper coals are not splits off the Wellington bed; on the contrary they maintain a fairly consistent stratigraphic separation both from the Wellington bed and from each other.

SEAM SPLITS

Contrary to the notion expressed by Hacquebard *et al.* (1967) that the Wellington coal bed shows no sign of splitting and rejoining, on closer examination splits appear to be fairly common. The Wellington coal bed itself is made up of three thinner but closely adjacent coals, which locally come together to form a composite bed of workable thickness (Bickford, 1987; Bickford and Kenyon, 1988). The nomenclature of the coal bed varies according to its workable section:

TABLE 4-3-1
TABLE OF FORMATIONS

Wellington Rider coal bed;		This entire assemblage constitutes Wellington coal bed.
Upper Parting dirt band;		
Upper Wellington coal bed, containing several thin dirt bands;	Where Lower Parting is absent, this comprises the Wellington Main coal bed.	
Lower Parting dirt band;		
Lower Wellington coal bed, locally containing a dirt band.		

The recognition of the limits of the composite coal bed is based upon the thickness of the intervening dirt bands. As it is generally impracticable to mine dirt bands thicker than 0.6 metre, whenever one of the dirt bands exceeds this thickness, the coal bed is considered to have split into its component coals.

Splitting and rejoining of the Wellington seam appear to be most common in the southwestern corner of the coalfield, in Wolf Mountain and Extension collieries. Splits are particularly well exposed in the main entries of Wolf Mountain colliery, where they open to the southeast and southwest. Outside this area, the Wellington coal bed splits southwest of the Harewood colliery (Figure 4-3-3), and west of the Wellington colliery. In general, the Wellington coal bed appears to split more frequently in a westward direction, while to the east it tends to pinch out and ultimately disappear.

SEDIMENTOLOGY

Nanaimo Group sediments, including the Wellington coal bed, were deposited on a surface of high relief (Clapp, 1914; Muller and Atchison, 1971). Basement knobs and ridges projected above the general level of sedimentation and exerted a profound influence on the thickness and character of the basin-filling sediments. Geological mapping along the basin margins, and boreholes within the basin, indicate that some of the basement ridges, for example the prominent ridge of volcanic rocks north of Departure Bay, were emergent features at the time of deposition of the Wellington bed. Another isolated basement knob was encountered by boreholes and mine workings at Wakesiah colliery, west of Nanaimo.

Immediately adjacent to these basement hills, the Wellington seam tends to be thin and high in ash, grading locally into black coaly mudstone. At greater distances from the basement hills, the coal attains its normal thickness; in some cases the basement hills appear to have sheltered the coal-forming swamps from the influx of sediments, resulting in the accumulation of unusually thick coal bodies in their lee (Buckham, 1947a).

Away from basement hills, the Wellington coal is characteristically bright banded and very hard. Its inherent ash content ranges from 6 to 10 per cent, and appears to be highest in the Rider coal, which is often marked by cleat-filling calcite and pyrite. A distinctive thin band (1 to 3 centimetres) of speckled, "oolitic" coaly mudstone lies in the middle of the Rider coal at Wolf Mountain. In thin section this band shows subangular grains of quartz with carbonate rims, in a matrix of dark, presumably organic-rich clay. This band may represent either an intensely altered ash band or an eolian sand deposit. In any event it is laterally persistent and forms a useful marker for detailed coalbed correlations.

Dirt bands in the Wellington seam typically consist of soft, intensely sheared dark brown to black coaly mudstone (the "rashes" and "blaes" of old miners' reports). Rootlets and thin-shelled pelecypods are occasionally present, suggesting deposition in a shallow, low-energy lagoonal or lacustrine environment. As the dirt bands thicken into split areas, they pass into compact, brown, rooty siltstone and very fine-grained silty sandstone, which may represent crevasse-splay deposits (Bickford, 1988). Ultimately these lithologies give way to erosive-based, crossbedded and rippled fine-grained sandstones with occasional mudstone laminae which may represent clay-draped point bars and fluvial channel fills. Angular, twisted blocks of coal are occasionally found at the base of these erosive sandstones and probably represent blocks of peat ripped off the channel margins.

The floor of the Wellington seam is almost always the hard, medium to coarse-grained sandstone of the East Wellington Formation. The surface of this sandstone is usually marked by a few centimetres to a decimetre of black sandstone, rich in organic matter and extensively penetrated by coalified roots. Most of the roots are quite narrow, suggesting they supported the growth of sedges rather than large shrubs or trees. The contact of the Wellington coal with its floor is abrupt except in the extreme northwestern corner of the coalfield, west of Wellington colliery. In this area the basal few decimetres of the seam often contain lenses and stringers of coaly sandstone and sandy coal, suggestive of post depositional disturbance, perhaps by waves acting to partially lift the coal-forming peat.

Stone rolls are a common feature of the floor surface. At Wolf Mountain colliery it is possible to examine them in detail. Here they are of two types: linear rolls striking to the northwest with a steep face down to the southwest, and sinuous rolls with no preferred orientation. The linear rolls may represent relict beach ridges, as described by Bunnell *et al.* (1984). The sinuous rolls probably represent the margins of meandering streams or tidal channels incised into the floor prior to peat deposition.

The lateral persistence of its component coal plies, the presence of extensive rooting in its floor, the occurrence of coalified stumps in its partings and its immediate roof suggest that the Wellington coal is not of detrital origin. Coal-forming peat may have accumulated in a forested coastal swamp, which in most places was sheltered from direct attack by waves except during major storms.

MINING HAZARDS

While mining conditions are generally good in the Wellington coal bed, the potential for major accidents remains. This is amply demonstrated by the historic record of explosions and inundations of mine workings, commencing with the 1888 explosion and fire at Wellington colliery, in which 77 miners were killed.

The major source of accidents, as opposed to fatalities, is falls of roof or top coal. The immediate roof of the Wellington coal bed is generally a laminated siltstone or silty mudstone, which although relatively strong, will readily undergo bed separation if not adequately supported soon after exposure by mining. Prior to the availability of rockbolts, this sort of material was difficult to support by means of timber alone, and accounted for many accidents owing to its tendency to fail without warning.

The presence of thin rider coals above the worked section, particularly at White Rapids and Wolf Mountain, is a contributory factor to bed separation and subsequent roof falls. The presence of a rider coal is particularly hazardous in that it may lie at such a height above the worked section that rockbolts may be anchored below the rider, resulting in the potential for massive failure of the strata underlying the rider. Where rider coals lie closer to the worked section, intervening strata may be unusually friable due to pedogenic slickensiding.

Compared with the other coals of the Nanaimo coalfield, the Wellington bed is not particularly gassy. Despite its low gas yield, gas may accumulate in poorly ventilated cavities and ignite on contact with naked lights (as happened at Wellington colliery), or by means of frictional sparking during roof falls (which may have happened at Extension colliery in 1909).

The hard, vitrinite-rich Wellington coal makes a large amount of dust during mining, and the fine dust is carried for long distances by ventilating currents, ultimately accumulating along mine roadways. Coal dust may have been involved in, and increased the violence of, some of the larger explosions. Systematic stone-dusting of mine workings has largely reduced this hazard, but a possibility of dust ignitions still exists due to incendive sparking at the coal face. Sparks may be generated when powered coal-cutters contact the hard, quartz-bearing sandstone floor of the Wellington seam.

Areas of oxidised coal along the outcrop of the Wellington bed are prone to spontaneous combustion, following mining-induced caving and crushing of the strata. The northern end of Extension colliery has been on fire since the late 1930s, hampering efforts to recover remnant pillars of coal. Besides the possibility of encountering an active fire, the smouldering coal generates carbon monoxide, which may migrate through subsidence cracks either into adjoining workings or to the surface. Spontaneous combustion thus represents a hazard both to continued mining operations and to the use of the overlying lands for residential development.

Oxidation of coal and timber in old workings results in the formation of carbon dioxide, which being heavier than air can accumulate in low points within the workings. Carbon dioxide poisoning has caused at least two fatalities to children who had crawled into old workings at Harewood colliery.

Several inrushes of groundwater and water-bearing sediment have occurred within collieries working the Wellington seam. While very few fatalities have resulted, this has been more the result of fortuitous timing of the inrushes, rather than precautions taken against their occurrence. The No. 4 mine at Extension broke through into water-bearing sand, gravel and peat underlying a lake; it was abandoned in 1917 following the failure of dams which had been built underground in an effort to contain these materials. In 1936, miners in Northfield colliery broke through into the flooded workings of Wellington colliery, owing to these older workings extending beyond the points shown on their abandonment plan. A similar inrush occurred at Beban colliery in 1937, resulting in three fatalities. In this case, flanking drillholes failed to detect the old flooded workings, perhaps due to them being at a different horizon within the thick coal bed being worked (Robert Bone, Senior Inspector of Mines, personal communication, 1988).

Because most of the workable remnants of the Wellington coal bed lie adjacent to old workings, their development will probably require dewatering of old workings by means of boreholes, preferably from surface so as to intersect the full thickness of the coal bed in which flooded workings may be present. Disposal of mine water should not be a major problem, as its quality is adequate for irrigation use, as already practiced at one golf course west of Departure Bay.

Residential or industrial development above shallow mine-workings may require costly stabilisation of the old workings in order to assure an adequate foundation for building construction. While most subsidence problems in the Nanaimo coalfield are related to the presence of old workings in the Douglas and Newcastle seams underlying the city centre, mining-induced subsidence over the Wellington coal bed has caused geotechnical problems in residential areas above the Wellington and East Wellington collieries (Douglas Pelly, consulting geotechnical engineer, personal communication, 1986).

One of the major difficulties inherent in development over areas of old workings is the lack of accurate mine plans. In response to this problem, a compilation plan has been prepared by Island Geotechnical Services Ltd. (Pelly, 1979). Copies of this plan may be obtained through the Nanaimo City Engineer's office.

POTENTIAL FOR FURTHER EXPLORATION AND DEVELOPMENT

Despite a long history of exploration and mining, the mineable extent of the Wellington coal bed has not yet been completely outlined. In some areas, for example to the west of Wellington colliery, the early disposition of coal rights was such that effective exploration was not carried out owing to parts of the prospective area being unavailable for drilling. These areas are now unavailable for further exploration as they have been built over by suburban housing tracts. In other areas, particularly at Harewood, boreholes did not always reach the Wellington coal bed, owing to erroneous correlations of the intersected strata.

In the northern part of the Nanaimo coalfield, the eastward extent of mineable Wellington coal is defined by a gradual pinchout of the seam, from its optimal thickness of about 2 metres, to a practical workable limit of about 0.8 metre. These thin sections were most extensively worked in the 1940s at Northfield colliery, with the assistance of then-modern technology such as longwall-face conveyors. Given modern economic conditions, it is doubtful coal this thin could be worked at a profit. Present practice, by way of comparison, is to consider the minimum workable thickness to range from 1.5 to 1.8 metres, depending upon available equipment.

The pinchout has been established by closely spaced drilling in the vicinity of Northfield and Departure Bay. It appears to extend generally southward under the city of Nanaimo, passing just to the east of Malaspina College, where it was established by workings in the old Wakesiah colliery. The southward prolongation of the mineable limit is not yet known beyond Harewood colliery, owing to lack of effective drill control.

Within the prospective area of the Wellington coal bed, much of the easily accessible coal has already been mined or rendered unworkable by proximity to flooded old workings. Proven reserves lie west of Wolf Mountain colliery and can be reached through existing workings. Remnants of Wellington coal may be present to the southeast of Wellington colliery, to the southeast of Harewood colliery, and to the east of the washout area which bounds Timberlands colliery. With the exception of Wolf Mountain, all of these areas would require drilling or underground development in order to establish mineable reserves. A modest additional potential exists for salvage mining, by open-cast excavation of outcrop pillars, along the margins of the old collieries.

FURTHER WORK TO BE DONE

During the 1989 field season, paleocurrent indicators such as framework imbrication, cross-stratification and channel scours will be mapped in the Extension Formation. The aim of this work will be to more clearly establish the directions of sediment transport in strata associated with the Wellington coal bed. Petrographic examinations will be completed on pillar samples taken from the Wellington coal bed at Wolf Mountain colliery, in order to estabish the relationship between the macroscopic appearance of the coal and its maceral composition. This work should lead to a better understanding of the coal bed accumulation conditions.

ACKNOWLEDGMENTS

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