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TECHNICAL NOTE

TRITIUM DATING OF WATER INFLOWS AT THE DONKIN-MORIEN PROJECT, NOVA SCOTIA

T.R.C. Aston*

*Research Scientist, Cape Breton Coal Research Laboratory, CANMET, 210 George Street, Sydney, Nova Scotia, B1P 1J3, Canada.

ABSTRACT

In January 1983, a limited programme of tritium analyses were undertaken on selected water inflows in the No. 3 tunnel at the Donkin-Morien Project, Sydney Coalfield, Nova Scotia. After a brief review of tritium dating and conditions at the Donkin-Morien site, the results are discussed in relation to the potential age and source of the inflow water. The results indicate that the feeders are at least 'modern' in age (pre-1952), but because of the limited data available and the problems associated with the technique, they should only be used to supplement the analysis and interpretation of existing hydrological and hydrochemical data sets presently being collected.

INTRODUCTION

The Sydney Coalfield is located on Cape Breton Island which lies at the north-eastern end of Nova Scotia. During the late 1970's, an extensive drilling and geophysical programme by the Cape Breton Development Corporation (CBDC), defined an offshore coal resource block in the Donkin-Morien area of the coalfield, Figure 1. Subsequent feasibility studies resulted in the definition and implementation of the Donkin-Morien Project.

The initial phase of the Donkin-Morien project involves the development of two tunnels (Nos. 2 and 3) 3.5 km in length to intersect the Harbour seam.

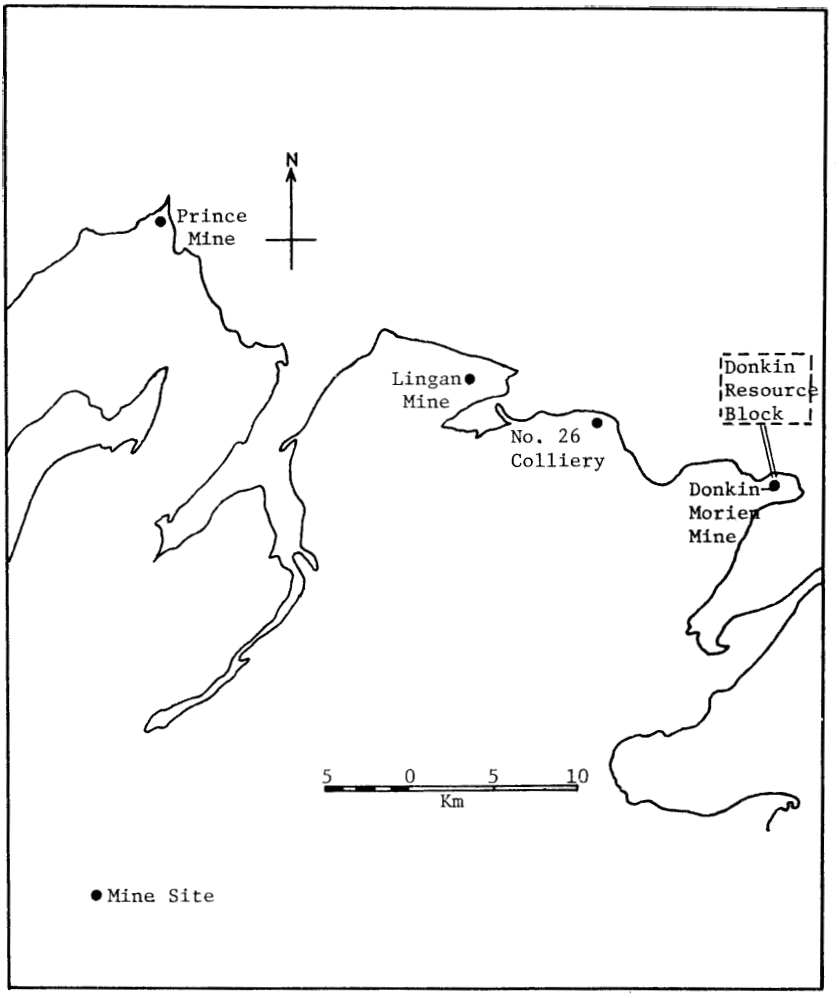

Figure 1 - Plan of the Sydney Coalfield showing the Donkin-Morien mine site and resource block

At present, 1027 m of the No. 3 tunnel has been driven, at a 20% decline, using drill and blast methods, while a 7.6 m diameter full face tunnel boring machine is being used to drive the No. 2 tunnel.

In the first 500 m of the No. 3 tunnel, water feeders were encountered which constituted a nuisance rather than a hazard to the tunnelling operations. All the available data regarding these inflows has been collected and is currently undergoing analysis (1). In January 1983, staff from the Cape Breton Coal Research Laboratory (CBCRL) initiated a limited programme of tritium analyses on selected No. 3 tunnel inflows in an attempt to establish the age, source horizon and recharge mechanism of the ingress water. In the No. 2 tunnel only several minor water feeders have been encountered.

TRITIUM DATING GROUNDWATER

Tritium (^{3}H) is a natural radioactive isotope of hydrogen which is formed naturally by the dissociation of nitrogen following interaction with cosmic rays. It is also formed as a by product of thermonuclear testing and has a half life of 12.26 years.

The widespread testing 'above ground' of thermonuclear devices between 1952 and 1962 drastically increased the amount of tritium in the atmosphere, swamping natural background levels. The intermittent testing of such devices has also led to the introduction of periodic pulses or peaks of tritium to the atmosphere.

Tritium usually enters the hydrological cycle via precipitation. Figures 2 and 3 show tritium variations in precipitation over Canada (2) and Great Britain (3) for the period 1953 to 1975. The periodic nature of atmospheric tritium levels is shown in Figures 2 and 3 as well as the relationship between peak levels and those years in which major 'above ground' testing occurred. However, it should be remembered that the amount of tritium input to the earth's surface is variable and dependent on climatic conditions as illustrated by the following statement (3):

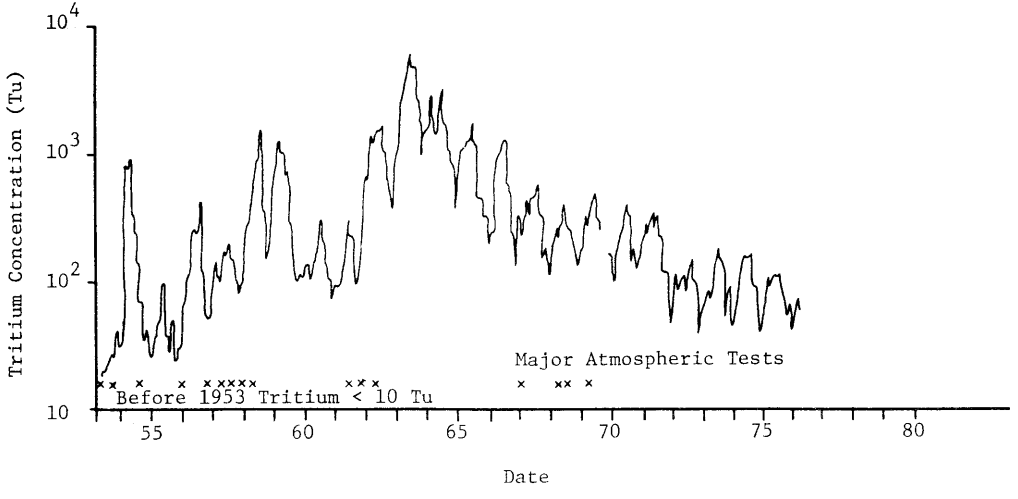

Figure 2 - Tritium concentrations in precipitation (mean monthly values), Ottawa, Canada (2)

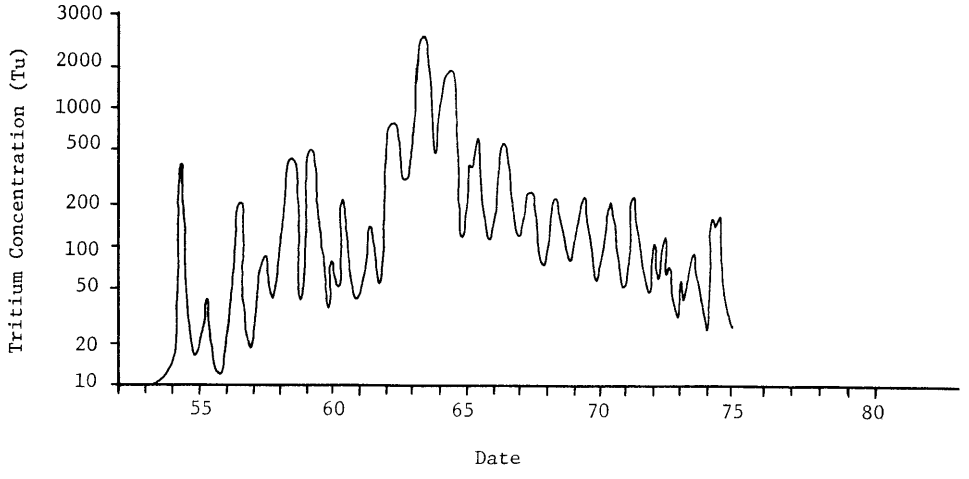

Figure 3 - Tritium concentrations in precipitation over the United Kingdom (3)

'In oceanic areas vapour exchange between the atmosphere and sea will be far more effective than precipitation in removing tritium concentrations from the atmosphere. Over land areas the removal of atmospheric tritium is principally via precipitation, which is extremely variable and dependent on the various climatic, land distance and orographic influences affecting precipitation. It is therefore apparent that tritium concentrations reaching the earth's surface can be exceedingly variable in both time and space. Consequently, tritium levels in groundwater via both direct and indirect recharge can also be extremely variable'. A detailed discussion of the distribution of hydrogen isotopes (deuterium and tritium) in Canadian waters is given by Brown (4).

If the problems associated with using tritium are recognized, then in simplified terms the apparent age of groundwater can be determined by its classification according to one of three types:

1) No detectable tritium - Older than 100 years
2) Low levels of tritium - Pre-1952
3) High levels of tritium - Post-1952

A discussion of the application of hydrogen isotope hydrology to mining related groundwater problems can be found in (6, 7).

GEOLOGICAL CONDITIONS IN THE NO. 3 TUNNEL

The Donkin-Morien tunnels have been driven through typical Coal Measures strata which comprises of interbedded sandstones, siltstones, mudstones and coal seams. Structurally, the strata dips gently offshore (NNE) at between 4 and 9 degrees.

The No. 3 tunnel and the initial 1300 m of the No. 2 tunnel were driven in a massive sandstone unit, 35 m thick, which varies in lithology from laminated to thickly bedded and from fine to coarse grained. Extensive carbonaceous partings and cross bedding also exist.

The massive sandstone unit or 'Portal' sandstone is overlain by an interbedded sequence of sandstone, siltstones, mudstones and shales which vary in composition with both depth and areal extent. The 'Portal' sandstone unit is underlain by a similar sequence of interbedded argillaceous strata. In the vicinity of the outcrop, both the massive sandstone and interbedded argillaceous strata exhibit weathering to a depth of over 2 m.

Three minor joint sets intersect the area, and are found in both the tunnels as well as the outcrop.

WATER OCCURRENCES IN THE NO. 3 TUNNEL

In tunnel No. 3 water seepage and inflows were encountered during the first 500 m of drivage. They appeared to be associated with a clay seam which loosely followed a conglomerate band near the top of the main sandstone unit. During the first 300 m, the conglomerate and clay layer were often exposed in the tunnel section which resulted in water inflows at these locations. In addition, inflows were also experienced from open fissures created by the drill and blast operations used in this section. Between 300 and 500 m, the nature of the inflows changed with water only being encountered in rock bolt holes which intersected the clay/conglomate horizon.

DATA COLLECTION

Water samples were collected from two locations in the No. 3 tunnel and one surface site. The underground samples were collected from water 'feeders' at chainage 300 m and 500 m (vertical depths 70 and 100 m respectively), while the surface water sample was collected from the sea at the nearby Donkin beach. In each case, the samples were collected in sterile one litre plastic screw top bottles on site, sealed and subsequently shipped for analysis.

Samples were analyzed for tritium and inorganic carbon - 14 counts. The tritium count was measured using liquid scintillation counting over a 100 min.

period. The inorganic carbon - 14 count was measured using acid digestion/ distillation preconcentration followed by liquid scintillation counting.

The laboratory data is given in Table 1:

	Name	Analyte 1	Analyte 2
Name		He(pC/L)	C14 (pC/L)
S 1	SEAWATER	1200 +/- 800	15
S 2	300 M	1700 +/- 1200	15
S 3	500 M	1500 +/- 1100	15
S 4	DISTILLED WATER	2000 +/- 1300	15
S 5	DEIONIZED WATER	1600 +/- 1100	15
S 6	TAP WATER	1800 +/- 1200	15

Table 1 - Tritium counts (pC) for the field and laboratory collected samples.

ANALYSIS AND DISCUSSION OF RESULTS

Test results in Table 1 give the tritium concentration as a value in pico curies (pC) per litre. In (2), (3) and (5) the atmospheric and groundwater tritium values are always expressed in Tritium Units (TU's). It is therefore necessary to convert pC/litre to Tritium Units, where 1TU = 3.26 pc.

The analysis of tritium in samples of distilled, deionized and tap water was also undertaken with the field samples.

Sample	No.	Minimum	Mean	Maximum
Seawater	51	123	370	615
300 m	52	153	523	892
500 m	53	123	461	800
Distilled Water	54	215	615	1015
Deionized Water	55	153	492	830
Tap Water	56	184	553	923

Table 2 - Tritium values (TU) for the field and laboratory collected samples.

Table 2 shows the minimum, mean and maximum results obtained for the samples in Tritium Units (TU). When reviewing Table 2, extreme caution must be exercised when attempting to interpret the results.

In both Tables 1 and 2 a large potential error exists for each of the results. It is therefore necessary to assume that for each of the six samples analyzed, the mean value is representative of the inherent tritium concentration.

The samples collected from chainage 300 and 500 (523 and 461 TU) show greater tritium concentrations than the seawater sample (370 TU). The samples of distilled, deionized and tap water show a variation between 492 and 615 TU, indicating that modern values can be expected to lie in this region. The

seawater value of 370 TU is lower than that indicated by the comparable modern samples (492-615 TU).

A direct comparison of the modern and underground samples (Nos 51-56) suggests that all are modern in age. Lloyd (3) states that 'a concentration of over 4 TU can provide a signature for the water type, inferring simply that modern recharge is a feature'. Since the chainage 300 and 500 m feeders register 523 and 461 TU respectively it is inferred that both source aquifers were recharged during the post 1952 period. A detailed examination of Figure 2 suggests a recharge period between 1962 and 1967.

Recent values for tritium concentrations in precepitation at Ottawa [8] indicate background values in the range 20 to 100 TU. The modern samples (Nos 54-56) in the study show values between 490 and 615 TU, which are greater than would be expected. Two explanations for the high tritium values given in Table 2 must therefore be considered:

1) Thermonuclear atmospheric testing in the period late 1981 to 1983 significantly increased the background levels. The underground feeders would therefore be very modern in age (less than 5 years) with rapid recharge occurring either vertically downwards from seabed or down dip from outcrop. However, communications with various authorities [8] indicates that insignificant atmospheric testing has occurred since 1981 and that low background tritium levels should be present in the environment.

2) An examination of Table 1 shows that all the samples analysed have potential errors in the region of 65 to 73%. The data may therefore be suspect due to errors incurred during the analytical procedure.

It is concluded that either the underground feeders are very modern in age or the data is unreliable. The small amount of atmospheric nuclear testing recorded during the early 1980's coupled with the magnitude of the potential errors in Table 1 suggests that the data is unreliable and should only be used with extreme caution and in conjunction with additional hydrological and hydrogeological information.

CARBON - 14 DATING

No meaningful results were obtained from the Carbon - 14 analyses undertaken. In each case, the carbon - 14 count was found to be less than pC 15 and the exact value not specified because of insufficient sensitivity in the test method.

If future work were to be undertaken, it should be determined beforehand whether the analytical method can be refined sufficiently in order to give a definite carbon - 14 value.

CONCLUSION

A direct examination of the results suggests that the two underground feeders encountered at chainage 300 and 500 m are discharging water which is 'modern' in age. However, a more detailed examination reveals that the data should be considered unreliable and only used with extreme caution and in conjunction with additional hydrological and hydrogeological information. Finally, additional sampling to identify the source horizons of the No. 3 tunnel feeders should only be done once a thorough review of the analytical procedures for determining tritium have been undertaken.

ACKNOWLEDGEMENTS

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