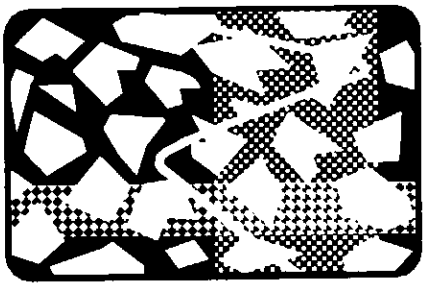

Project WAPA: Evaluation of a lead-zinc occurrence in Middle Devonian carbonates of northern Saskatchewan

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Introduction

In 1973, in the course of a drilling program to assess coal deposits within the Cretaceous Mannville Group, Brascan Resources Ltd. discovered traces of carbonate-hosted base metal sulphide mineralization in the holes that penetrated the underlying Middle Devonian succession in an area south of Lac La Ronge, north-central Saskatchewan (Figure 1). The area was investigated by Canadian Occidental Petroleum (Minerals Division), beginning in 1976, under a program called Project WAPA, named after Wapawekka Lake. The project later became a joint venture with the Saskatchewan Mining Development Corporation. No deposits of economic significance were located by a geophysical and exploratory drilling program, and thus the joint venture was dissolved and the project abandoned.

Stratigraphy

In the Project area, Cambro-Ordovician sandstones overlie Precambrian basement. These in turn are unconformably overlain by Middle Devonian carbonates of the Lower and Upper Elk Point Subgroups. These Middle Devonian carbonate rocks are in turn unconformably overlain by clastics of the Cretaceous Mannville Group.

The stratigraphic column shown in Figure 2 illustrates the published column of Fuzesy (1980) for northern Saskatchewan as compared with the local nomenclature of Kent (1976), who served as a consultant on the project and whose work provided the basis for this study. The Cambrian Deadwood Formation and Ordovician Winnipeg Formation can be clearly differentiated elsewhere, but in the Project WAPA area both are near their depositional limits and not readily distinguishable. They are designated Cambro-Ordovician here and consist of weakly cemented quartz sand with some argillaceous matrix material. Their thickness varies greatly from a maximum of about 160 m to less than 2 m in the northern portion of the area.

Middle Devonian rocks are represented by carbonate units of the Elk Point Group. In this area, the Elk Point Group differs considerably from the evaporite-bearing units of Alberta and Saskatchewan, and correlations are based on similarities in marker horizons. The Basal Redbed unit of the project area is believed to be correlative with the Ashern Formation of the Lower Elk Point Subgroup. The red beds contain fine to coarse quartz sand in a matrix of reddish brown claystone, and the unit varies considerably in thickness from a few centimetres up to about 6 m. In practice, however, the basal redbeds (Middle Devonian?) are difficult to distinguish from the underlying Cambro-Ordovician sandstones.

The Lower Elk Point Subgroup was designated as the Meadow Lake Formation by Fuzesy (1980) and includes the Ashern Formation and the Meadow Lake beds of earlier workers. Owing to dissolution or non-deposition of the Lotsberg and Cold Lake salts, correlation with the units of the Central Alberta Basin is not possible. In the Project WAPA area, however, Kent recognized two distinctive units, which are informally called the Smoothstone River Formation and Contact Rapids Formation. These are dolomites basically, which can be differentiated on the basis of minor compositional and colour differences.

The Smoothstone River Formation, the host for sulphide mineralization, onlapped a positive element in Middle Devonian times

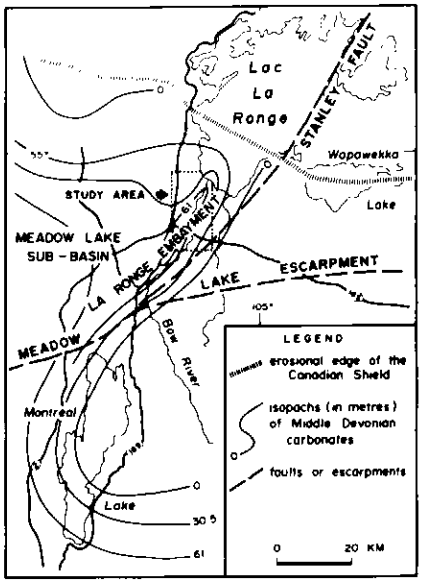

Figure 1 *The location of the Project WAPA area showing structural features discussed in the text.*

and accordingly thins rapidly to the east from maximum thickness of about 17 m. The lower member is called informally the "quartzose arenaceous bed", and consists of dolomitic mudstone with minor wackestone lenses. The upper member is called informally the "grey argillaceous bed", and is also a dolomitic mudstone but contains much less detrital quartz.

The overlying Contact Rapids Formation contains lower, middle, and upper members, which differ mainly in colour. The unit is about 30 m thick in most of the area but thins to 2 m to the east.

The Upper Elk Point Subgroup is represented only by the Winnipegosis Formation. It averages only two metres thickness in the Project WAPA area, but varies from complete absence to approximately 15 metres. The unit consists of yellowish orange or brown sucrosic dolomite containing solution-modified fragments of brachiopods, mollusks and crinoid stems.

Unconformably overlying the Middle Devonian strata are strata of the Lower Cretaceous Mannville Group. These consist of grey, variably argillaceous, carbonaceous sands and sandstones with subordinate shales and mudstones. Seams of lignite, up to 2 m thick, and fragments of older carbonate rocks are common near its base. In the Project WAPA area, the Mannville Group is about 100 m thick.

Geology

As illustrated in Figure 1, there is a general tendency for all units to thin to the north toward their depositional limits with the adjacent Precambrian Shield. The Lower Elk Point Subgroup rocks, however, represent the easternmost extension of the Central Alberta Basin. The narrow basin, lacking salt beds, that extends to the main portion of the Central Alberta Basin is called the Meadow Lake Sub-basin. A marked thickening of the Cambro-Ordovician units created a topographic high in Lower Elk Point times, which separated the Central Alberta Basin from the Saskatchewan Basin to the east and south. This topographic high is called the Meadow Lake Escarpment, and it marks the southerly limit of Lower Elk Point deposition. It was not until deposition of the Winnipegosis Formation that the barrier formed by the Meadow Lake Escarpment was transgressed, and the Upper Elk Point Subgroup was deposited in the enlarged Elk Point Basin consisting of the Northern Alberta, Central Alberta and Saskatchewan Basins of Lower Elk Point time.

A significant feature is an apparent basement fault known as the Stanley Fault from its extension in the Shield to the north. It appears to have marked a positive Precambrian basement element in Cambro-Ordovician times, as these units thin markedly as they approach from the east. West of the Stanley Fault, however, is a marked

Table 1 Sulphur Isotopic Composition of Pyrite from Project WAPA

Sample No.	$\delta^{34}S$ (‰)
9-78-3	-3.1
10-78-2	+21.6
11-78-2	+22.3
11-78-3	+23.2
12-80-4	+28.1
15-78-2	+34.0
33-80-2	+28.4
41-78-4	+21.9

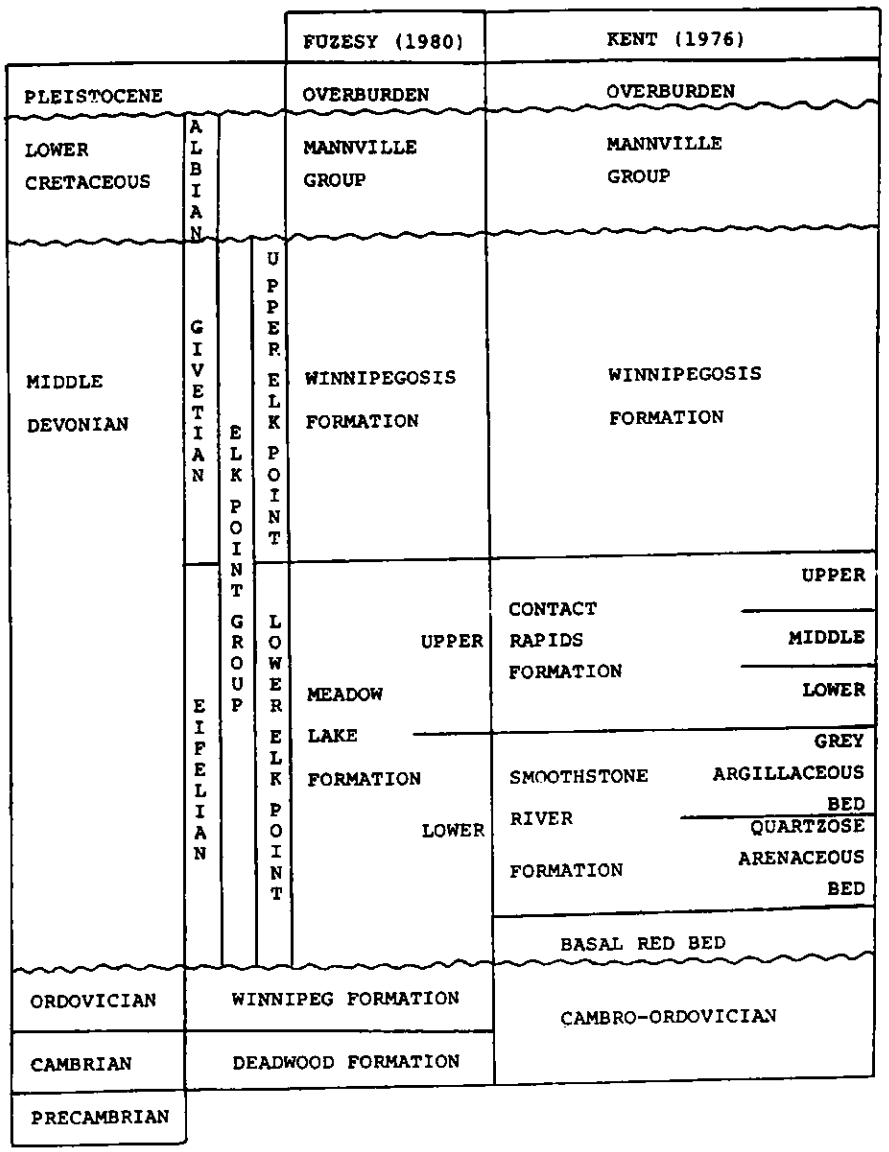

Figure 2 *General stratigraphy of the Project WAPA area.*

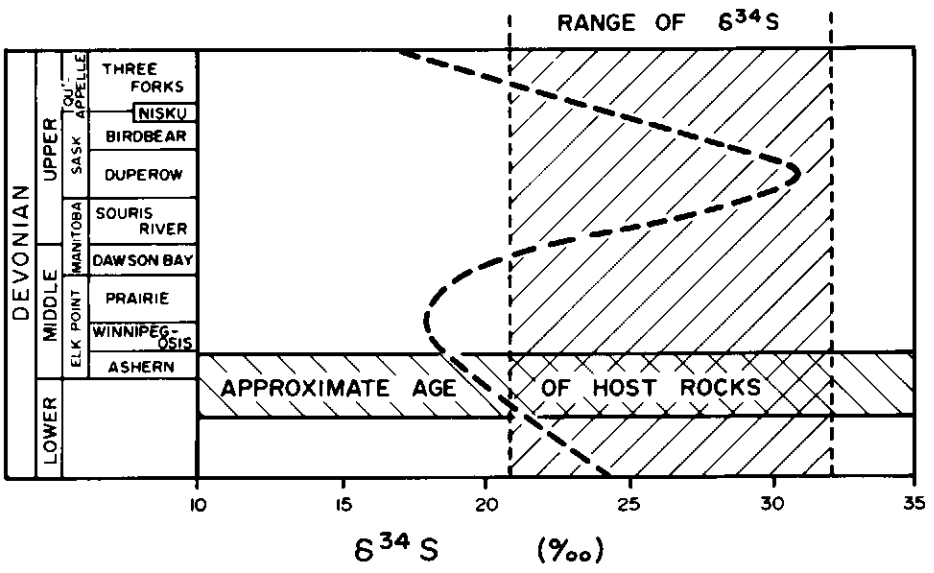

Figure 3 *The sulphur isotopic composition of Devonian evaporites as a function of age. (Modified after Holser and Kaplan, 1966). The vertical band contains the range of compositions of Project WAPA pyrites (except sample 9-78-3; range is +21.6 to +34.0 $\delta^{34}S$‰) whereas the horizontal band indicates the approximate age of the host rocks.*

basement low in which Middle Devonian rocks formed a northwesterly trending trough called the La Ronge Embayment. Most of the lead-zinc occurrences are found in this trough.

Within the Smoothstone River and Contact Rapids Formations several zones of brecciation are found. The brecciation is of two types. One represents an early diagenetic stage of evaporite solution, in which fragments are recemented by dolomite. A second type of brecciation was created by later solution of evaporites, possibly salt but probably mainly gypsum. The solution of evaporite beds may have occurred during a period when the units were in the vadose zone. Further evidence of such a process may also be manifested in partial dedolomitization of some portions of the section. Whatever their origin, the brecciated zones served as the site of deposition of sulphide mineralization within the Smoothstone River Formation.

Economic Geology

Occurrences of traces of galena and sphalerite in breccias of the Smoothstone River Formation inspired a drilling program in which the joint venture team drilled on a grid containing 43 holes, in addition to five earlier holes completed by Brascan and one by the Saskatchewan Department of Mineral Resources. None of these holes encountered more than traces of mineralization, and, in considering as well that the depth of the mineralization was in excess of 100 m, the project was abandoned.

Although Project WAPA was unsuccessful from the standpoint of leading to the development of a lead-zinc orebody, it is instructive to analyze the occurrences in order to attempt to decide whether an environment for formation of carbonate-hosted ores existed, and whether additional potential is present in north-central Saskatchewan.

Some light is cast upon the question of the origin of the sulphide occurrences by preliminary fluid inclusion homogenization measurements we have made on dolomitic crystals and sulphur isotopic data we have obtained from sulphides. The limited data obtained to date show the existence of a population of inclusions that homogenized at about 100°C and one that did not homogenize at temperatures as high as 180°C. The reasons for the existence of these two populations is unclear at present, but in any case, they indicate that the dolomite is of hydrothermal origin.

Sulphur isotopic data obtained from various pyrite samples are given in Table 1. The first sample, 9-78-3, is slightly negative, possibly indicating that this is diagenetic pyrite formed by bacterial reduction of sulphate. The remaining samples are all highly positive, suggesting reduction from seawater sulphate without fractionation, *i.e.*, non-biogenic, presumably hydrothermal processes. The foregoing data clearly indicate that the sulphides could not have formed, as has been suggested, at the time of dissolution of evaporites in the Lower Elk Point Subgroup. This theory proposed that metals released during dissolution combined with bacterially-reduced sulphide to form the sulphide occurrences. On the contrary, the metal- and sulphur-carrying solutions must have been produced in a relatively high-temperature environment, or at least by an abiogenic process.

The range of suphur isotopic compositions obtained is interesting in light of suggestions made earlier that there was a significant secular variation in the composition of Devonian seawater sulphate. Figure 3, modified after Holser and Kaplan (1966), shows the apparent variation in the composition of seawater sulphate as a function of time (dashed line). The vertical band is the range of compositions of Project WAPA pyrite, whereas the horizontal band represents the approximate age of the host rocks for the mineralized zones. It appears that an Upper Devonian source and a variable one at that may have supplied the sulphate for reduction in the Project WAPA area.

Kent (1980) previously obtained an isotopic analysis of lead in a Project WAPA galena. The lead is highly enriched in radiogenic isotopes and lies well beyond lead-lead growth curves. The lead yields futuristic ages and thus is of J-type, also known as anomalous lead.

Conclusions

Metal- and sulphur-bearing brines may have migrated from deep in the Elk Point Basin to its margin, travelling through Cambro-Ordovician sandstone aquifers. These sandstones and possibly the Precambrian basement may have enriched the leads in radiogenic isotopes. The solutions were focussed upward into the overlying Middle Devonian carbonates at the pinch-out of the Cambro-Ordovician sands. Precipitation occurred preferentially in collapse breccia zones formed by earlier evaporite solution.

The above mechanism should be adequate to form an economic deposit, provided sufficient quantities of metal-carrying solutions were expelled from the Elk Point Basin through the La Ronge Embayment. Paleohydrologic factors, however, appear to have been inadequate in this case. However, given the viability of the mechanism, it does appear that potential for lead-zinc mineralization is present in north-central Saskatchewan.

Acknowledgements

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