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Abstract: The Meadowville disseminated zinc-lead occurrence lies in grey, plant debris-rich sandstone, the base of the late Carboniferous Boss Point Formation, overlying red granitic conglomerate of the Claremont Formation. At Meadowville (NTS 11E/10), as well as at the Leitches Creek lead-zinc occurrence and the Yava lead-zinc deposit, underlying evaporite-bearing Canso and Windsor group rocks contain unconformities and faults. At Meadowville these discontinuities permit fluid access from underlying, potentially zinc-rich, mafic conglomerate and basalt.

Drilling down dip from Meadowville failed to discover significant base-metal sulphide mineralization. The hole was tentatively interpreted to cross the ore zone into the Claremont Formation. Reinterpretation of the core shows that the hole terminated in grey, intraformational conglomerate within the Boss Point Formation, probably not reaching the mineralized zone.

Plant debris-rich sandstone unconformably overlying faulted evaporitic strata is a likely exploration guide for sandstone Pb-Zn deposits in late Carboniferous rocks of the Canadian Maritimes.

Résumé : L'indice de Meadowville se compose d'une minéralisation disséminée de zinc-plomb encaissée dans un grès de couleur grise riche en débris de plantes situé à la base de la Formation de Boss Point du Carbonifère tardif, juste au-dessus d'un conglomérat rouge à fragments granitiques de la Formation de Claremont. À l'indice de Meadowville (SNRC 11E/10), tout comme c'est le cas à l'indice de plomb-zinc de Leitches Creek et au gisement de plomb-zinc de Yava, les roches de la succession sous-jacente qui appartiennent aux groupes à lithologies évaporitiques de Windsor et de Canso renferment des discordances et des failles. À l'indice de Meadowville, ces discontinuités auraient permis la circulation de fluides issus des basaltes et des conglomérats à fragments mafiques sous-jacents qui sont potentiellement riches en zinc.

Un sondage situé en aval-pendage de l'indice de Meadowville n'a pas permis d'identifier de quantités importantes de sulfures de métaux communs. Une première interprétation des données de forage laissait croire que le trou avait atteint la Formation de Claremont sans avoir traversé de zone minéralisée. Une nouvelle interprétation de ces données indiquerait plutôt que le forage du trou a été arrêté dans un conglomérat intraformationnel gris à l'intérieur de la Formation de Boss Point, et que celui-ci n'a donc probablement pas atteint la zone minéralisée.

Dans les provinces Maritimes du Canada, des grès riches en débris de plantes reposant en discordance sur des strates évaporitiques faillées constituent de toute évidence un guide d'exploration pour les gisements de Pb-Zn dans des roches du Carbonifère tardif.

INTRODUCTION

Late Precambrian to Early Paleozoic marine quartzite units overlying granitic rocks of the Baltic Shield host a number of sandstone Pb-Zn deposits, e.g. Dorotea, Laisvall, and Vassbo. After the advent of land plants greatly enhanced the possibility of terrestrial reduced environments, such deposits were able to form in alluvial sequences (Bjørlykke and Sangster, 1981). A Canadian example of the latter is the Yava deposit of Cape Breton Island. This deposit formed in plant material-bearing fluvial sandstone of the late Carboniferous Silver Mine Formation where it overlies a granitic basement at the pinch out of the intervening early Carboniferous, evaporite-bearing Mabou and Windsor groups (Sangster and Vaillancourt, 1990).

One set of genetic models for the Scandinavian deposits holds that the granitic basement was impermeable. Groundwater leached metals from the basement during weathering and transported them in basal quartz arenite of the unconformable sedimentary cover (Bjørlykke and Sangster, 1981). Sangster and Vaillancourt (1990) applied this model to the Yava deposit. Alternatively, hot metalliferous brine was pressed out from a deep sedimentary basin in the west during Caledonian compression (Rickard et al., 1979).

A second set of models requires that the basement was permeable. The metals could have been leached during deep convection of meteoric water or groundwater, stimulated by high heat-producing granite (Bjørlykke et al., 1991). Alternatively, metals were leached from the basement along lithological heterogeneities and along faults reactivated during the Caledonian orogeny (Romer, 1992). Featured in both sets of models was deposition of the metals by mixing of ore fluid with reduced sulphur-bearing fluid in basal quartz arenite, the first available permeable unit in the sedimentary cover (Romer, 1992).

Apart from the Yava deposit, a number of small Pb-Zn occurrences are hosted by grey plant-debris-rich sandstone of the Late Carboniferous of the Canadian Maritimes. This report documents field observations on the geological environment of one of these occurrences at Meadowville, Nova Scotia (Fig. 1, 2). Its aim is threefold; to comment on the possible extent of this occurrence, to provide field criteria both for exploration for Carboniferous sandstone Pb-Zn deposits, and to provide data for genetic modelling of this type of deposit.

PREVIOUS WORK

Regional and detailed soil and basal till geochemical surveys by Bluestack Resources and BP Selco revealed an east-trending zinc-lead anomaly and minor Ba anomaly, open to the east, 3 km southwest of Meadowville in western Pictou County, Nova Scotia. Copper values were not above background. The anomaly overlies the base of the Boss Point Formation. Minor galena and oxidized Zn mineralization were noted in grey sandstone and calcareous pebble conglomerate float believed to belong to the Millsville Formation (stratigraphic nomenclature of Ryan (1985)) in the immediate area (Patterson, 1994). The Millsville Formation is now referred to as the Claremont Formation (Ryan et al., 1991). Local, abundant sandstone float also suggested that the mineralization may be hosted by sandstone (McCulloch, 1984). Two inclined exploration diamond-drill holes, M-1 and M-2, were drilled by Rio Algom Exploration in 1992 on the Meadowville anomaly in the lower part of the late Namurian–early Westphalian Boss Point Formation (Fig. 2). Assays of sulphide mineralization, disseminated in grey sandstone of the Boss Point Formation by Laboratoires Chemex of Rouyn, Quebec, for Rio Algom, showed both zinc and lead values both over 10 000 ppm in some samples from hole M-1 and smaller amounts from hole M-2 (Fig. 3). Hole M-1 did not reach the lower boundary of the Boss Point Formation, whereas hole M-2 penetrated the underlying conglomeratic Claremont Formation at 16.8 m (Patterson, 1994).

Rankin (1997) also interpreted Rio Algom's hole M-2 to have penetrated the underlying Claremont Formation and noted that galena was visible in several previously unsampled zones in core from downdip hole M-1. Mispec Resources Inc. drilled two holes, M-97-1 and M-97-2, totalling 330 m in February 1997, to test the downdip extension the Meadowville mineralized zone. Extensive sampling of these cores yielded only weakly elevated Pb-Zn values from M-97-1. Rankin (1997) interpreted calcareous pebble conglomerate in the Boss Point Formation as fluvial-channel lag deposits. He interpreted coarse conglomerate at the base of core M-97-1 to belong to the Claremont Formation while interpreting hole M-97-2 to have ended in the Boss Point Formation. This implied that the ore zone, if extending down dip from hole M-1, had been intersected by hole M-97-1. Assays by M-Tech Inc. showed that the maximum Pb value in core

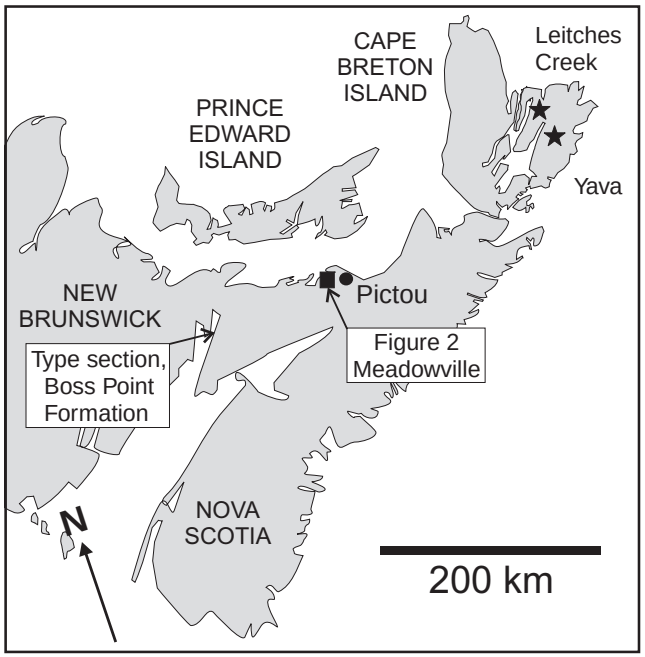

Figure 1. *Location map for the Meadowville and Leitches Creek Zn-Pb occurrences and the Yava Pb-Zn mine, Nova Scotia.*

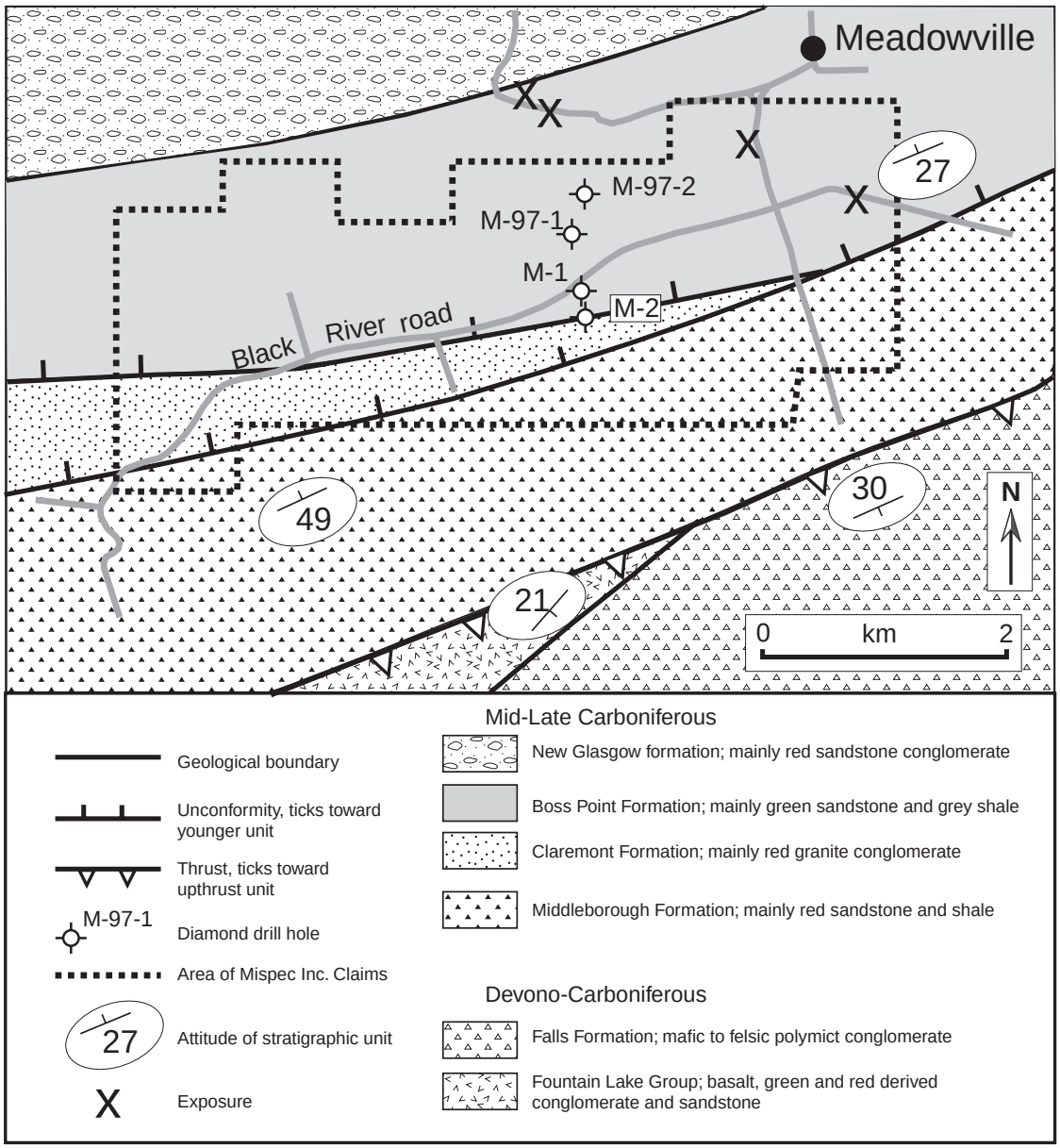

Figure 2. *Bedrock geology and location of diamond-drill holes on the Mispec Inc. Zn-Pb property, Meadowville, Nova Scotia.*

M-97-1 was 670 ppm and the maximum Zn value was 1450 ppm (Fig. 3). Absence of significant mineralization in holes M-97-1 and M-97-2 argued against extension of the orebody down dip from hole M-1. Consequently Rankin (1997) concluded that the mineralization in the area was mostly secondary and related to northeast-striking faults.

OBSERVATIONS

Cores M-97-1 and M-97-2 were examined by the writer (Fig. 4a) and consist essentially of interbedded units of grey sandstone and red mudstone. Rare units of black laminated mudstone are up to 70 cm thick. The sandstone units may be in the form of upward-fining cycles, commencing with a basal intraformational pebble conglomerate composed mainly of grey carbonate pebbles, with lesser amounts of black or grey mudstone pebbles and coalified wood fragments with rare associated pyrite. Some mudstone fragments are several centimetres in size and very angular. The sandstone units are grey-green and crossbedded or rippled, with flasers of fine-grained plant debris. Tops are rippled or flat bedded and may be mottled. These cycles may be stacked into units of alternating intraformational conglomerate and crossbedded sandstone. Large diagenetic carbonate nodules occur in the sandstone units.

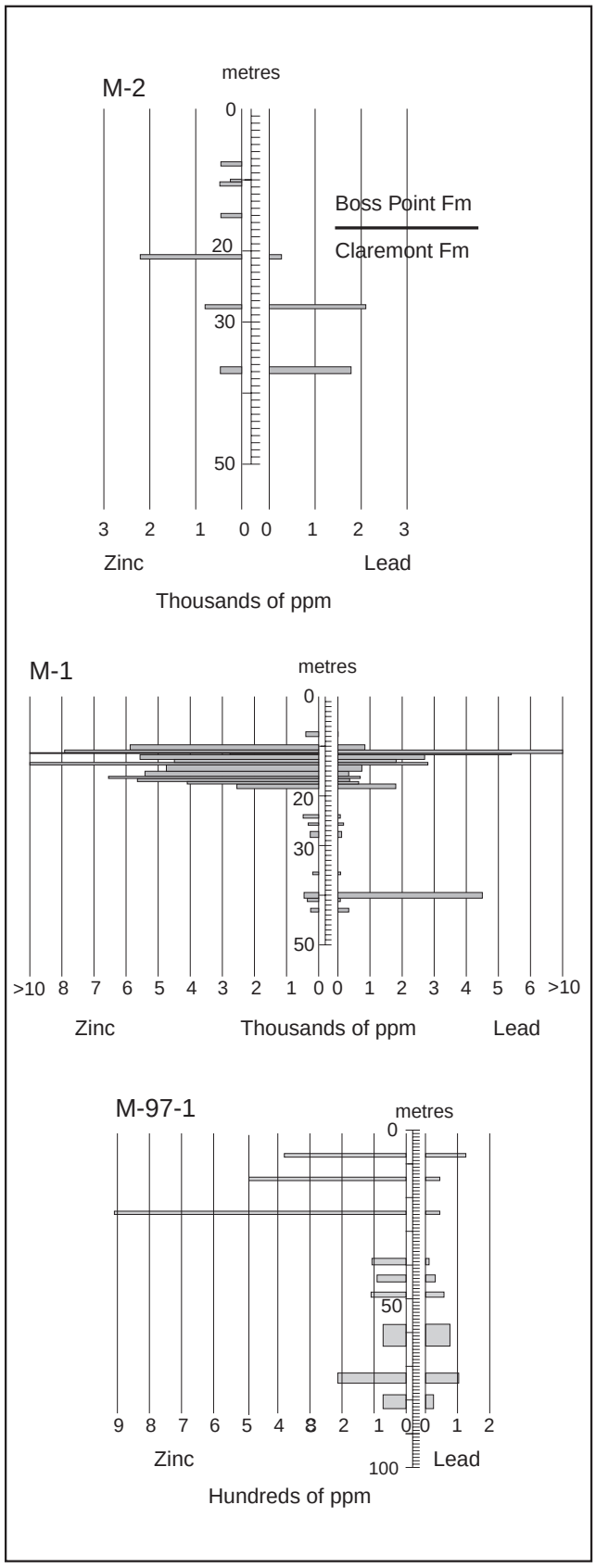

Figure 3. *Zinc and lead assays of sandstone samples from drill core at the Meadowville occurrence. For location of drill holes M-1, M-2 and M-97-1* see *Figure 2. For stratigraphic position of samples within drill cores* see *Figure 4.*

Interbedded red mudstone units are generally massive and contain fining-upward, rippled siltstone-mudstone beds. Calcrete nodules, calcite rhizoconcretions (concretions around roots), and green or oxidized rootlet traces are present, especially in the upper part of the mudstone units. In other cases the mudstone units are terminated with mottled units with grey tops. In one case red mudstone with calcite rhizoconcretions is overlain in turn by red mudstone with subordinate green root mottles, mottled mudstone, and massive dark grey mudstone.

Core M-1 consists almost entirely of stacked grey sandstone and intraformational conglomerate as described above, with minor amounts of grey mudstone with carbonate nodules. The upper 16.8 m of core M-2 is similar to cores M-97-1 and M-97-2 except that mottled mudstone is more abundant than red. Nodular carbonate cement is present in the sandstone of both cores M-1 and M-2. The lower 29 m of core M-2 consists of interbedded green or pink sandstone and granitic orthoconglomerate, with clasts up to 5 cm across.

Sulphide paragenesis in the Meadowville drill cores, as observed in polished thin section from core M-1, consists of pyrite, followed in turn by galena and sphalerite, disseminated in grey sandstone. Lead and zinc mineralization in core M-2 is scattered and the highest values, more than 2000 ppm, occur within the granitic conglomerate of the Claremont Formation. In core M-1 zinc mineralization is clearly more abundant than lead. Nearly all of the high values are confined to a 9 m thick interval of grey, crossbedded sandstone (Fig. 3). Assays from core M-97-1 are scattered and interestingly, like those of core M-1, have high zinc values in a sandstone-rich interval in the upper part.

DISCUSSION

The Boss Point Formation is a 800–1000 m thick, dominantly grey, lithic, fluvial sandstone formation that extends west from Pictou County to southeastern New Brunswick (Browne, 1990; Plint and Browne, 1994; Ryan and Boehner, 1994; Chandler et al., 1997). Conglomerate in the Boss Point Formation is intraformational and consists of layers of coalified plant debris and grey carbonate (calcrete, Brown and Kingston (1993)) and grey mudstone pebbles at the base of fluvial channel sandstone beds. Quartz-pebble conglomerate is minor (Ryan and Boehner, 1994) except in New Brunswick (McLeod, 1980).

Interpretation of the four drill cores agrees with the above description. At Meadowville the grey sandstone units are interpreted to be of fluvial channel origin, with intraformational conglomerate formed as channel lag deposits from floodplain carbonate nodules, transported woody debris, and locally eroded grey mudstone. Large angular mud fragments may have slumped from undercut banks. The red mudstone units were deposited on floodplains, with the laminated black mudstone units evidence of floodplain lakes. Calcrete- and rhizoconcretion-bearing, rooted and mottled units with grey tops were probably formed as soils.

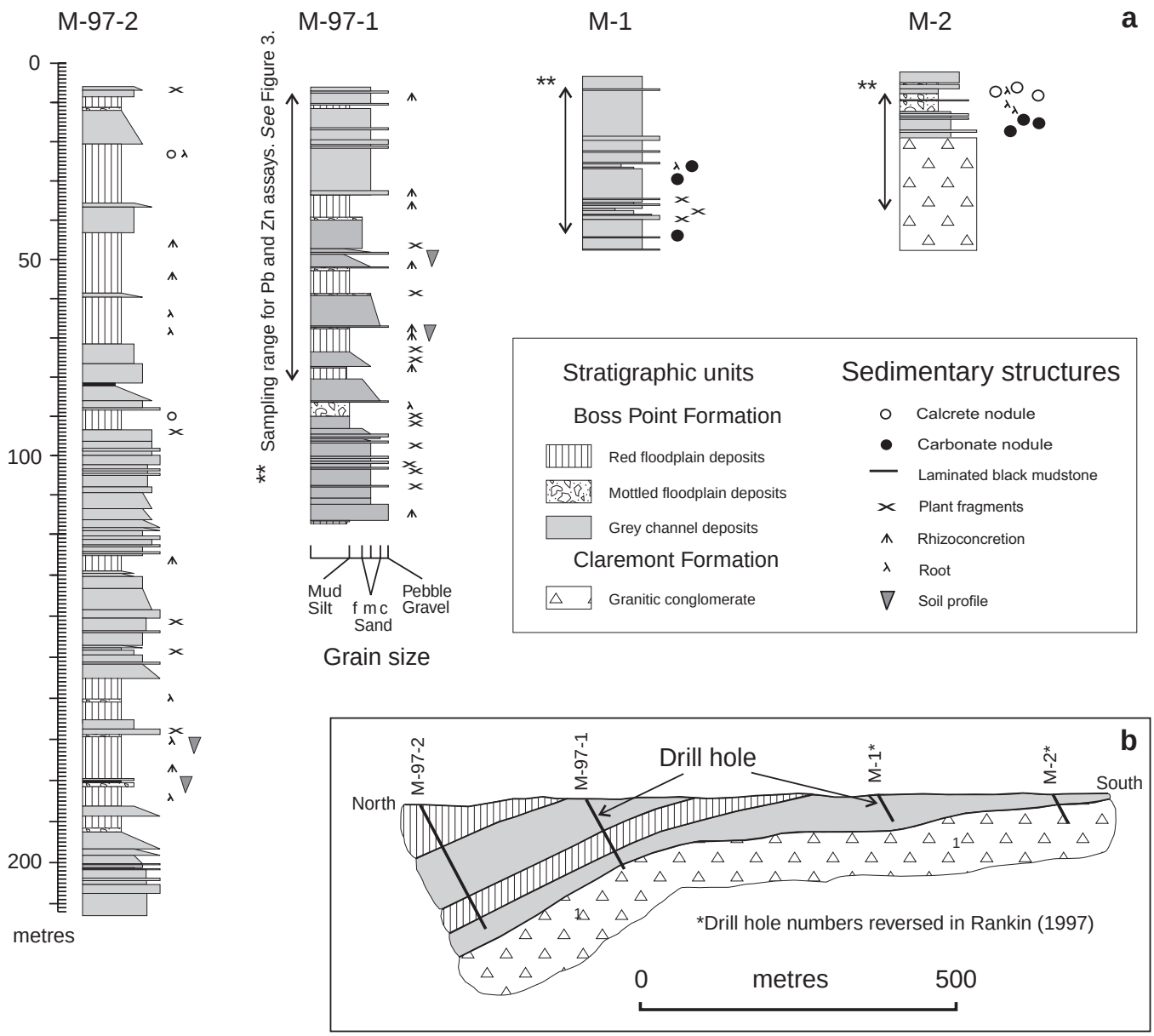

Figure 4. a) *Lithological logs of drill cores from the Meadowville occurrence, Nova Scotia. Two headed arrows show stratigraphic ranges of assays of Figure 3.* ***b)*** *Previous interpretation of drill holes by Rankin (1997).*

Generally, as in the type section at Boss Point, Nova Scotia, 125 km west of Meadowville (Fig. 1), the bulk of channel sandstone and floodplain mudstones are grey or green. Where the formation lies between redbed formations, as in the type section and in Pictou County, its upper and lower parts consist of red shale and red and green sandstone. At the type section these upper and lower redbed members are 165 m and 85 m thick respectively (Logan, 1845).

Siting of the four drill holes at Meadowville with respect to local geological mapping and the abundance of red versus grey mudstone in holes M-97-1 and M-97-2 makes it likely that these holes pass through the lower 'redbeds' of the Boss Point. Division of the Boss Point Formation at Meadowville into two sandstone and two mudstone units by Rankin (1997) in Figure 4b probably reflects lateral migration of fluvial channel sandstone complexes. The lower 29 m of core from hole M-2 consists of pink, arkosic grit, coarsening down to pink granitic orthoconglomerate, both unknown in the Boss Point Formation, but characteristic of the underlying Claremont Formation. Therefore the writer concurs with Rankin (1997) in the view that drill hole M-2 penetrates the Claremont Formation. All conglomerate in holes M-1, M-97-1, and M-97-2 is interpreted here as of the intraformational type, characteristic of the Boss Point Formation.

Therefore the writer suggests caution in accepting Rankin's (1997) tentative conclusion, illustrated in Figure 4b, that hole M-97-1 reached the top of the Claremont Formation. The writer's reinterpretation suggests that the stratigraphic level of the ore horizon penetrated in hole M-1 my not have been reached by hole M-97-1. Indeed it is not certain that the sandstone-rich units penetrated at the base of holes M-97-1 and M-97-2 correspond with that penetrated by hole M-1. Moreover, the weak Pb and Zn assays of hole M-97-1 should not be used to draw conclusions about the downdip extension of the mineralization in hole M-1 because they come from a higher position in the Boss Point Formation (Fig. 4a).

Exposure of the Boss Point Formation in the vicinity of the Meadowville drilling is very sparse (Fig. 2). Rankin (1997) showed only the boundary between the Claremont and Boss Point formations (Yeo, 1987) whereas later mapping of unweathered, heaved blocks (Chandler et al., 1997) revealed further information about the units underlying the Meadowville occurrence. This includes recognition of redbeds of the Namurian Middleborough Formation and recognition of the thrust that has elevated older basalt and felsic and mafic conglomerate of the Falls Formation and Fountain Lake Group (Fig. 2) against the Middleborough Formation. The lithologies of these units are a good source of base metals and their generally oxidized condition encourages early intraformational fixing of zinc and lead (Rose, 1989). The Middleborough Formation belongs to the Mabou Group and overlies the Windsor Group regionally (Ryan and Boehner, 1994). The Middleborough Formation contains bedded evaporite elsewhere on Cape Breton Island (Crawford, 1995) and the Windsor Group contains abundant evaporite (Howie, 1988). Furthermore, carbonate units of the Windsor Group contain economic quantities of Pb-Zn sulphide minerals (Graves and Hein, 1994; Sangster et al., 1998). Therefore brines formed from intraformational solution of these evaporite units are a likely source of base metal-chloride complexes (Rose, 1989; Sverjensky, 1989). In support of the above, exposures of the Windsor Group, with nearby brine springs, occur 15 km to the southeast of Meadowville.

Noteworthy here is the presence of the Yava sandstone Pb-Zn deposit (Sangster and Vaillancourt, 1990) at the base of the Silver Mine Formation, a late Carboniferous sandstone unit rich in plant material and lithologically similar to the Boss Point Formation, directly above an unconformity over the evaporite-bearing Canso and Windsor group units in Cape Breton Island. At Meadowville, two unconformities lying close beneath the Boss Point Formation and a southeast-dipping thrust plane 2 km to the southeast provide discontinuities along which subsurface brine may have moved. The Leitches Creek Pb-Zn occurrence, also of Cape Breton Island (Boehner and Giles, 1986) lies at the base of the fluvial South Bar Formation, a unit that is similar to the Boss Point Formation (Rust et al., 1987), and which overlies with marked unconformity (Gibling et al., 1987) sulphate-bearing red and grey strata of the early Namurian Canso Group (Boehner and Giles, 1986). Further, the sulphate-bearing, Visean Windsor Group, which also contains Pb and Zn showings, is upthrown by a northeast-striking fault less than 1 km to the west of the Leitches Creek occurrence.

Underlying granitic rocks may be the source of lead and zinc, and the marine host rocks a source of chloride brine for the Scandinavian deposits (Romer, 1992). Underlying quartz porphyry may be a lead source for the Carboniferous Yava deposit (Sangster and Vaillancourt, 1990). The Precambrian "sandstone zinc" George Lake deposit of Saskatchewan has a zinc-lead ratio of seven (Karup-Møller and Brummer, 1970). Its geological environment is similar to that of the Scandinavian sandstone lead deposits (Sangster, 1995), but arkose underlying the ore-bearing quartzite contains metavolcanic amphibolite. Sphalerite mineralization is more pervasive than galena in the Carboniferous, sandstone lead-zinc Terra Nova deposit of Cape Breton Island. Unlike the nearby Yava deposit, the Terra Nova overlies a more mafic granodiorite (Sangster and Vaillancourt, 1990). Granitic basement is absent beneath Meadowville, but mafic material is present (Fig. 2). The more mafic material underlying George Lake, Terra Nova, and Meadowville could explain the high zinc-lead ratio of these occurrences. At Meadowville, the underlying Pb- and Zn-bearing evaporitic rocks also have implications for interpreting the source of fluids and base metals for this type of mineralization in the terrestrial Carboniferous deposits of Nova Scotia.

Some questions remain to be solved. Are 'sandstone zinc' deposits a high zinc zone of sandstone lead-zinc deposits or are they a distinct class of deposit? How important is basement lithology in determining lead-zinc ratio? Are underlying evaporite units important in the genesis of terrestrial sandstone-hosted lead-zinc deposits?

CONCLUSIONS

Unlike the Scandinavian deposits, which are hosted in marine quartz arenite, the Meadowville occurrence lies in fluvial lithic-feldspathic arenite. Reinterpretation of drill core indicates that the Meadowville Zn-Pb occurrence might be more extensive down dip than suggested by Rankin (1997).

The geological environment of this occurrence is in general similar to that of some other sandstone Pb-Zn occurrences in Nova Scotia, the Yava deposit, and the Leitches Creek occurrence. These occurrences lie at the base of late Carboniferous, drab (unoxidized), fluvial, plant debris-rich, lithic sandstone formations. The underlying formations of the Mabou and Windsor groups contain labile redbed, evaporite, and Pb- and Zn-bearing carbonate units. These underlying units are characterized by presence of unconformities and faults or thrusts. This association of lithologies may be of use in exploring for sandstone lead and zinc deposits.

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