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UPPER CAMBRIAN AND LOWER (MIDDLE?) ORDOVICIAN SANDSTONES OF THE OTTAWA EMBAYMENT: SUMMARY OF LITERATURE

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REGIONAL TECTONIC AND STRATIGRAPHIC SETTING

The Precambrian surface is commonly mantled by a widespread regolith zone of highly weathered granitic detritus (Bailey and Cochrane, 1984b). As the Upper Cambrian sea transgressed from the Appalachian Geosyncline into Quebec, the Ottawa Embayment and through southern Ontario depositional units thinned, resulting in an overall transgressive succession of marine sandstone and dolomite resting unconformably on basement (Poole *et al.*, 1968). However, these strata, the Sauk Sequence of Sloss (1963), were partially eroded and subsequently overlapped by Middle Ordovician units of the Black River Group (Poole *et al.*, 1968). During the Early to Middle Ordovician, rejuvenation of the Algonquin Arch induced erosion of previously more extensive Upper Cambrian/Lower Ordovician strata from the crest (Bailey and Cochrane, 1984b). This is represented by the regional-scale, pre-Tippecanoe, or "Knox" Unconformity which truncates all earlier Palaeozoic strata in southern Ontario.

UPPER CAMBRIAN COVEY HILL FORMATION

Definition

The Potsdam Group refers to the variously named Late Proterozoic/Cambrian/Ordovician sequence of sandstone and conglomerate unconformably overlying the Precambrian basement of Eastern Ontario, southern Quebec and northern New York (where the type section is located) (Williams and Telford, 1986). It thins to the north and west and pinches out over the Frontenac Arch (Lewis, 1971). Williams and Wolf (1982) proposed carrying the name Covey Hill Formation from Quebec into Ontario to refer to the lower quartz-feldspathic sandstone and pebbly sandstone unit underlying the Nepean Formation in the Ottawa Embayment (Fig. 1).

Depositional Setting and Thickness

In Quebec the Covey Hill is up to 610 m thick, lying unconformably on basement, and overlain unconformably by the Lower Ordovician Cairnside Member of the Chateauguay Formation (equivalent to the Nepean Formation) (Lewis, 1971). In eastern Ontario the thickness ranges from several hundred metres in the east to 0-9 m in the Ottawa area, to 0 m at the outcrop edge of the Frontenac Arch (Williams and Wolf, 1982; Williams and Telford, 1986). It is unconformably overlain and overlapped by the Lower Ordovician Nepean Formation (Williams and Telford, 1986). Wynne-Edwards (1967) noted the common, but localized, occurrence of a regolith of greenish arkose and conglomerate, or simply deeply-fractured and weathered basement rocks along the edge of the Arch. At this pinchout edge the Covey Hill may be present only as local pockets in paleotopographic low points on the Precambrian unconformity surface (Wynne-Edwards, 1967) or be preserved in down-faulted basement blocks (Wolf and Dalrymple, 1984). The Covey Hill is unfossiliferous, but likely of Late Cambrian age (Williams and Telford, 1986).

Lithology

The Covey Hill Formation comprises interbedded noncalacareous feldspathic sandstone and rounded conglomerates with minor mudstone beds (Lewis, 1971; Williams and Telford, 1986). Sandstones are light grey to reddish to greenish, thin to thick bedded, fine to coarse grained and generally laminated (Williams and Telford, 1986). They are composed of quartz and

pink feldspar, rounded to subrounded, poorly to well sorted, with hematitic coatings (Williams and Telford, 1986). Scattered pebbles and cross bedding are common (Williams and Telford, 1986). Conglomerates are grey to red, thick bedded, composed of pebble to boulder size clasts which are poorly to well sorted and subangular to subround (Williams and Telford, 1986). Numerous Precambrian basement lithologies are represented (Williams and Telford, 1986). Both Lewis (1971) and Williams and Telford (1986) suggest alluvial fan/ braided fluvial depositional environments.

Sedimentology

Wolf and Dalrymple (1984) described and interpreted the Covey Hill as follows, and suggested a reference locality in a quarry near Mill Pond Conservation Area (Leeds Co., S. Burgess Twp., lot 6, conc. II and III) with 13 m thickness exposed (Fig. 2A). They found five erosionally-bounded units arranged into two fining-upward sequences, from feldspathic conglomerate to quartzitic medium sandstone. The lower sequence was characterized by easterly paleocurrent flow, whereas the upper was characterized by northerly paleoflow. Pebble imbrication and crude horizontal stratification characterize the conglomerates whereas large-scale planar, and medium-scale trough, crossbedding characterize the sandstones. The sediments were interpreted as the result of deposition in distal alluvial fan/proximal braided fluvial environments in a setting influenced by tectonic movement on the nearby Rideau Lake Fault. Paleohydraulic analysis suggested a channel depth of about 4 m. The Covey Hill Formation may have originally covered a much greater portion of eastern Ontario than is preserved today (Wolf and Dalrymple, 1984).

LOWER ORDOVICIAN NEPEAN FORMATION

Definition

The Nepean Formation was named by Wilson (1937) to denote the 80-90 m of Potsdam sandstone between Precambrian basement and the lowest dolostone bed of the March Formation in the Ottawa-St. Lawrence Lowland. As there are no complete exposures, no type section was designated but it was inferred to be likely Lower Ordovician in age, representing the basal transgressive deposits over the uneven erosional surface of the Frontenac Arch (Wilson, 1964) (Fig. 1).

Depositional Setting and Thickness

The Nepean Formation is equivalent to the Cairnside Member of the Chateauguay Formation (Potsdam Group) in southwestern Quebec and unconformably overlies and overlaps the ?Upper Cambrian Covey Hill Formation to lie with variable thickness on the Precambrian erosional surface (Wynne-Edwards, 1967). It is sharply, but conformably, overlain by sandy dolostone of the Lower Ordovician March Formation (Wynne-Edwards, 1967; Brand and Rust, 1977; Williams and Telford, 1986). The Nepean ranges 60-160 m thick in the Ottawa area, thickening to the east into Quebec and thinning to an erosional edge to the west and south (Greggs and Bond, 1972; Williams and Telford, 1986). There is no equivalent strata west of the Frontenac Axis, in the main area of southwestern Ontario (Bailey and Cochrane, 1984b). Sandstone from the Nepean was extensively quarried west of Ottawa to be used in construction of

the Parliament Buildings (Greggs and Bond, 1972).

The Queensway roadcut, where 6.85 m of Nepean is exposed on Highway 417 west of Ottawa (on the same bedrock ridge as the old quarries), was designated by Greggs and Bond (1972) as a reference section, and by Brand and Rust (1977) as the type section, although the lower 3 m of the formation is not exposed (Greggs and Bond, 1972) (Fig. 2B).

Age

Greggs and Bond (1972) suggested a lowest Tremadocian age, younger than the type Potsdam. Brand and Rust (1977) recovered lower Arenigian conodonts from the upper Nepean and lower March at the type section, confirming the Early Ordovician, rather than Late Cambrian, age of the Nepean. Other good outcrops occur north of Kingston and over the crest of the Frontenac Arch (Greggs and Bond, 1972; Wolf and Dalrymple, 1984). Brand and Rust (1977) suggested that slight age differences between the St. Lawrence River and Ottawa may indicate progressive northward transgression of the Early Ordovician sea over the flank of the craton.

Lithology

The Nepean Formation comprises thin to thick bedded, generally cream-coloured orthoquartzitic fine to coarse sandstone and minor quartz-pebble conglomerate which weathers grey to brown to rusty yellow colours (Wilson, 1964; Wynne-Edwards, 1967; Greggs and Bond, 1972). Dark grey to brown, pebble to cobble quartzitic conglomerate and coarse sandstone are common near the base, and contain subangular to rounded clasts set in a matrix of fine to coarse grained, silica-cemented sandstone (Wilson, 1964; Greggs and Bond, 1972; Williams and Telford, 1986). Sandstones are thin to medium bedded, moderately to well sorted, subround to rounded, fine to coarse grained and are over 99% quartz (Wilson, 1964; Wynne-Edwards, 1967; Greggs and Bond, 1972; Williams and Telford, 1986). Hematitic coatings are common on grains (Williams and Telford, 1986) and accessory heavy minerals include zircon, magnetite and tourmaline (Wynne-Edwards, 1967). Silica cement is most common in the lower part, lending a resistant nature to the rocks, whereas calcareous cement is more common in the upper part, resulting in more friable sandstone (Wilson, 1964; Wynne-Edwards, 1967; Williams and Telford, 1986). Bailey and Cochrane (1984a) suggest that there is little porosity in these rocks.

Sedimentology

Sedimentary structures include medium scale cross bedding, ripples, mudcracks, abundant vertical burrows, thin partings of brachiopod fragments and large vertical water-escape structures ("pillars") (Wynne-Edwards, 1967; Greggs and Bond, 1972; Williams and Telford, 1986). Brand and Rust (1977) noted the presence of channelized forms near the base of the type section. Ripple crests have very variable orientations in the Ottawa area (Greggs and Bond, 1972) but paleocuurrent data from crossbeds in the correlative Cairnside Formation of Quebec yielded ESE transport directions. *Skolithos* and *Diplocraterion* are the most common burrows, especially in the upper part of the formation, and bioturbation increases toward the tops of individual beds (Greggs and Bond, 1972). The only identified shells are of the inarticulate brachiopod *Lingulella* (Wilson, 1964).

Interpretations suggest that basal coarser sediments may represent fluvial gravels with large scale trough crossbeds, overlain by aeolian cross bedded sandstone, overlain by shallow marine rippled and burrowed sandstone in an overall transgressive sequence (Brand and Rust,

1977; Williams and Telford, 1986; Wolf and Dalrymple, 1984). The Nepean passes gradationally upward into the sandy dolostone of the shallow marine March Formation.

Wolf and Dalrymple (1984) described and interpreted three facies within the Nepean north of the Kingston area as follows. In the lower Nepean, over the crest of the Frontenac Axis, well sorted and rounded medium grained sandstone with thin conglomerate lenses is characterized by very large scale, simple, sweeping crossbeds, adhesion ripples and large arthropod crawling traces. This facies was interpreted as the deposits of aeolian coastal dunes with interspersed minor ephemeral steam gravels. Typical Nepean facies in the Ottawa Embayment comprise laterally continuous, cyclically interbedded beds of well sorted and rounded fine to medium sandstone with silica cement. In addition, alternations of herringbone cross bedded units and completely bioturbated units are common. These sediments represent shallow marine, tidally-influenced facies. The third and least extensive facies comprises trough crossbedded quartz arenite with *Skolithos* burrows, deposited in tidal inlet or marine bar, or even shoreline, settings.

LOWER ORDOVICIAN MARCH FORMATION

Definition

The term March Formation was proposed by Wilson (1937) for the Early Ordovician aged transitional beds between the Nepean Formation sandstones and the Arenigian aged Oxford Formation limestones in southeastern Ontario (Fig. 1). The base may be disconformable, sharply overlying the Nepean or the Precambrian, and the top is conformable (Wilson, 1946). The unit is of late Tremadocian age, from conodonts (Greggs and Bond, 1971; Bond and Greggs, 1973). Although no complete sections are known, it ranges 7-47 m thick, is generally 18-20 m thick, and thickens to the east (Wilson, 1964; Greggs and Bond, 1971; Williams and Telford, 1986).

Greggs and Bond (1971) and Bond and Greggs (1973) established a series of well-exposed reference sections along Highway 401 in the Brockville area. In the Ottawa area the best outcrop is in the Armbro Quarry at South Gloucester (Williams and Telford, 1986).

Lithology

In general, the formation consists of grey, interbedded sandstone, dolomitic sandstone, sandy dolostone and dolostone, although in the Brockville area dolostone is absent. Sandstones are generally thin to thick bedded, fine to coarse grained, well sorted, subround to round and either calcite-cemented (friable), or silica-cemented (resistant) (Wilson, 1964; Williams and Telford, 1986). Cross beds, ripple marks and burrows are common, and at many locations sandstones are completely bioturbated (Greggs and Bond, 1971; Bond and Greggs, 1973; Williams and Telford, 1986).

Dolomitic sandstone and sandy dolostone, when present, are brown-grey, thin to thick bedded with abundant burrows and calcite vugs (Wilson, 1964; Williams and Telford, 1986). Dolostones may be sublithographic to medium crystalline, with algal lamination, calcite vugs and disseminated rounded fine to coarse grains of quartz throughout, especially near the base (Wynne-Edwards, 1967; Williams and Telford, 1986).

Sedimentology

Greggs and Bond (1971) and Bond and Greggs (1973) informally defined upper and lower

members in the Brockville area. There, the lower 27 m comprises grey fine to coarse sandstone, totally bioturbated (except for a few white quartz sandstone beds with *Skolithos* burrows), and contains abundant conodonts, organic matter and up to 50% calcareous cement. The upper 20 m is predominantly thick bedded, white to buff medium sandstone with siliceous cement, some burrowing (*Diplocraterion*, *Skolithos*), abundant crossbeds, ripples, erosional bases and desiccation cracks. These authors postulated that the lower member represents shallow marine, relatively slow sedimentation, somewhat deeper than either Nepean or upper member sediment, which represent more rapid deposition in shallow intertidal environments (Greggs and Bond, 1971; Bond and Greggs, 1973).

LOWER (?MIDDLE) ORDOVICIAN ROCKLIFFE FORMATION

Definition

The term Rockliffe Formation was first proposed by Wilson (1937) for the Lower-Middle Ordovician interbedded sandstone and shale well-exposed in the Rockliffe Park area of Ottawa (Williams and Telford, 1986). The lower contact is likely a disconformity sharply overlying the Lower Ordovician Oxford Formation (Wilson, 1964), and the top is a disconformity placed at the upper limit of thick shale interbeds overlain by the Middle Ordovician Shadow Lake sandstones (Williams and Telford, 1986) (Fig. 1). The unit is therefore likely of Chazyan or lowest Middle Ordovician age, older than the Black River Group (Wilson, 1964). It is unclear whether this unit should be considered as the latest portion of the Sauk Sequence (Sloss, 1963) or as the earliest manifestation of the Tippecanoe Sequence (Sloss, 1963). Its thickness is about 48-52 m (Williams and Telford, 1986), but increases to the east, and decreases to the west onto the Precambrian Shield (Wilson, 1964).

Lithology

A lower member of interbedded sandstone and shale and an upper member of interbedded sandstone, shale, limestone and silty dolostone are evident in outcrop (Williams and Telford, 1986). Wilson (1964) states that a thin basal conglomerate is locally present and implies that shale is the dominant lithology. Sandstones are light grey to greenish, thin to thick bedded, calcareous to noncalcareous and fine grained with minor coarse beds (Williams and Telford, 1986). Crossbedding, ripples, desiccation cracks, flutes and burrows are common (Williams and Telford, 1986). Shales are dark grey to green to maroon. Limestones, common in the upper member, are either shaley and fine-crystalline in western areas, or medium crystalline with stylolites and crossbeds in eastern areas (Williams and Telford, 1986). Minor silty dolostones are grey, fine crystalline and display prominent conchoidal fracture.

Sedimentology

Deposition likely occurred in a shallow subtidal to supratidal setting, with periodic exposure. Lithological variation and ichnofossil variation suggest water deepened to the east and clastics were derived from the Precambrian to the west (ie. Frontenac Axis) (Williams and Telford, 1986).

LIST OF FIGURES

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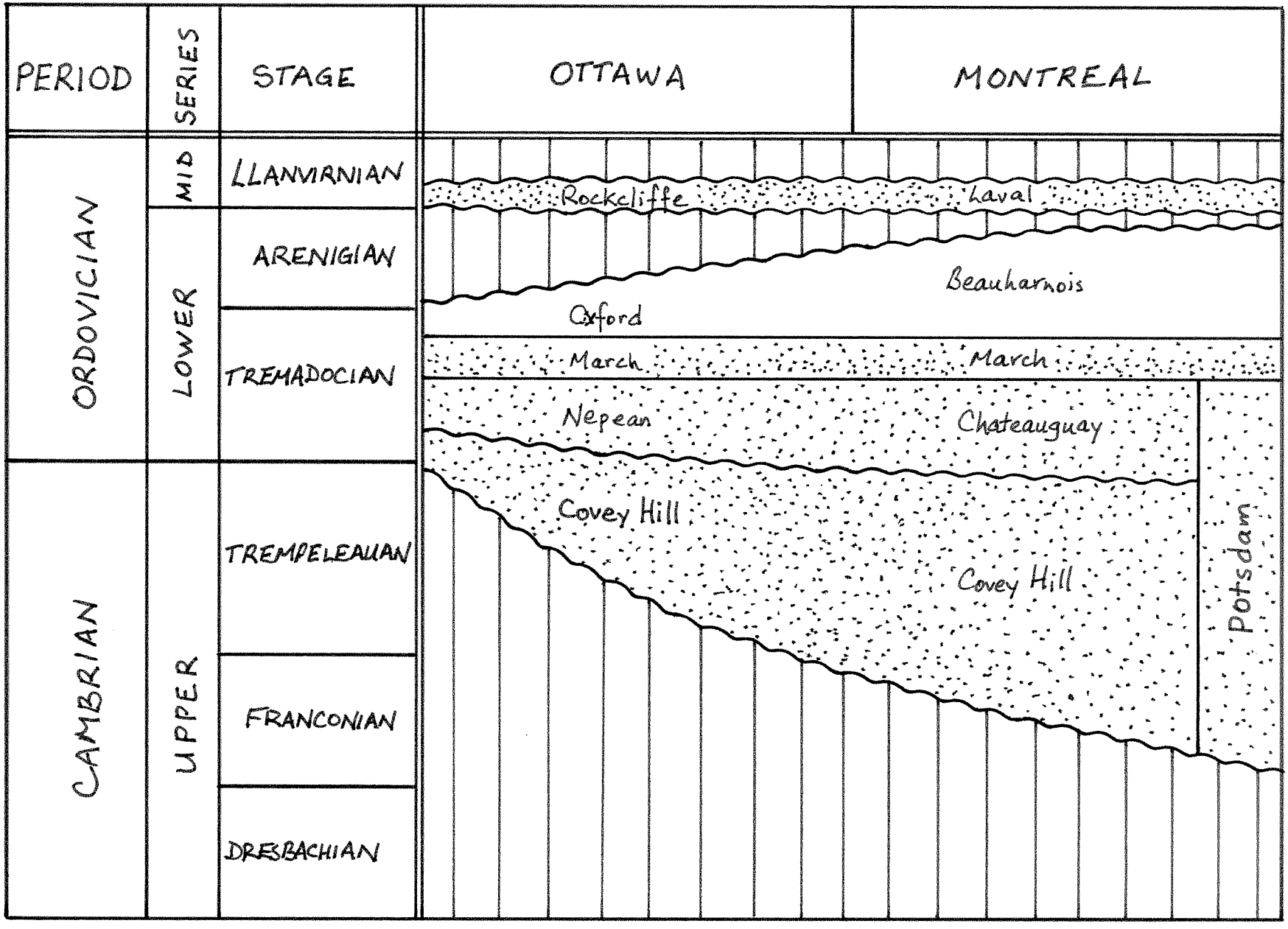
PERIOD
SERIES
STAGE
OTTAWA
MONTREAL
ORDOVICIAN
MID
LLANVIRNIAN
LOWER
ARENIGIAN
TREMADOCIAN
CAMBRIAN
UPPER
TREMPELEAUAN
FRANCONIAN
DRESBACHIAN
Rockcliffe
Laval
Beauharnois
Oxford
March
March
Nepean
Chateauguay
Covey Hill
Covey Hill
Potsdam

FIGURE 1.

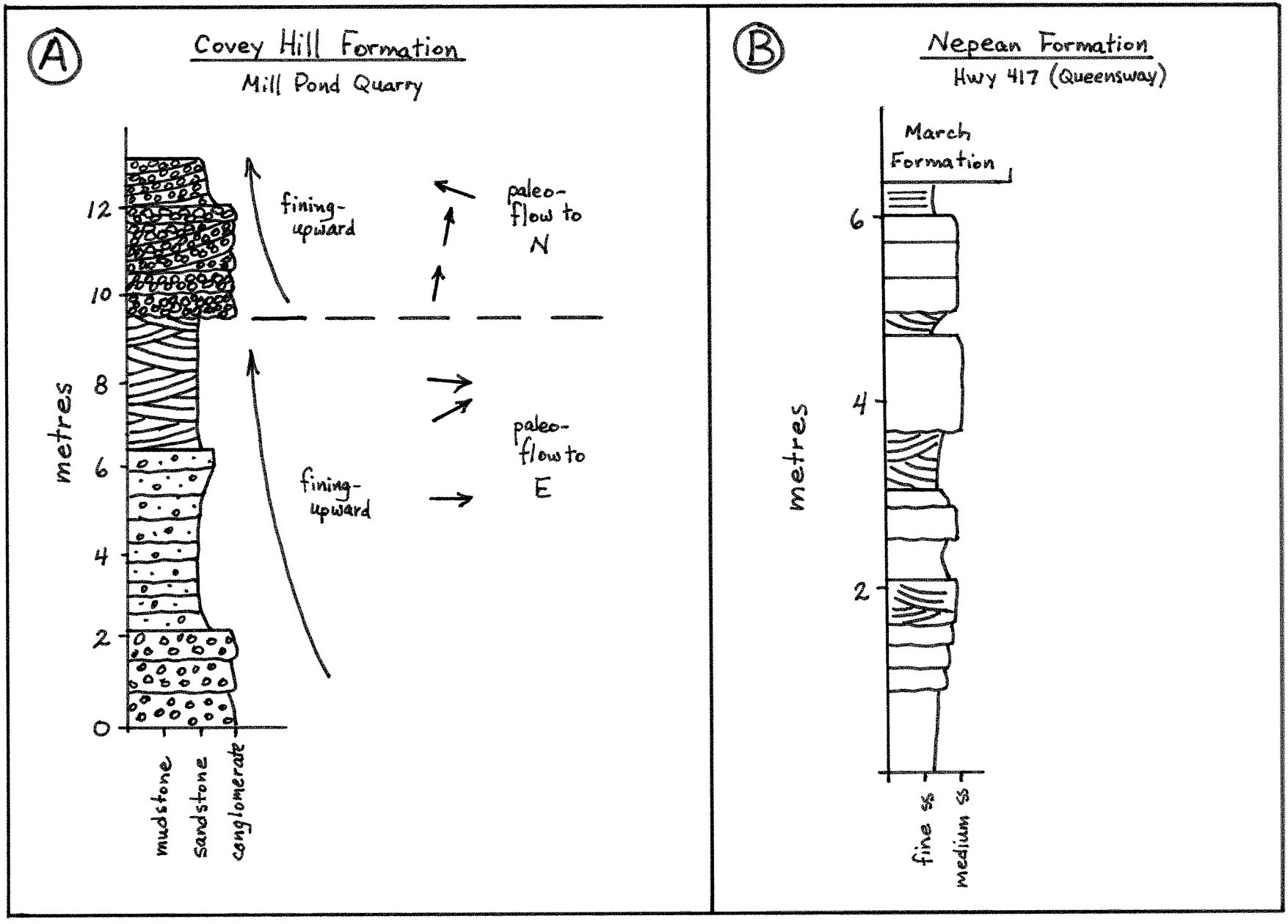
A
Covey Hill Formation
Mill Pond Quarry
metres
0
2
4
6
8
10
12
fining-upward
fining-upward
paleo-flow to N
paleo-flow to E
mudstone
sandstone
conglomerate
B
Nepean Formation
Hwy 417 (Queensway)
March Formation
metres
2
4
6
fine ss
medium ss

FIGURE 2.