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SEDIMENTOLOGY, PALEONTOLOGY, PROVENANCE AND REVISED STRATIGRAPHIC STATUS OF POLYMICTIC, DEEP-SEA CONGLOMERATES IN THE AREA OF POINT LEAMINGTON, NOTRE DAME BAY

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ABSTRACT

In the Point Leamington area, Ashgill–(?)Llandovery conglomerates conformably overlie and interfinger with the upper Caradoc–(?)Llandovery turbiditic sandstones of the Point Leamington Formation. The conglomerates formed on a deep-sea apron through debris-flow resedimentation of shelf siliciclastic deposits and coeval reef carbonates. Abundant epiclastic detritus, fragments of granitoid rocks, chert debris and chromite originated in an older composite source of deeply dissected, possible magmatic arc complexes, obducted ophiolites and accreted back-arc volcano-sedimentary formations. Copious intraformational sedimentary debris has been derived from entrenched turbiditic deposits of the Point Leamington Formation. The age and depositional setting of the conglomerates appear incompatible with their former assignment as 'Goldson Formation'. The type deposits of the Goldson Formation from Goldson Arm and Pikes Arm of New World Island are Late Llandovery and they formed in a shallow-marine environment. In the present report, the conglomerates from the Point Leamington area, informally referred to as Randels Cove conglomerate (RCC), are thought to be equivalent of polymictic, deep-sea fan deposits of the lower–middle Llandovery, upper Milliners Arm Formation, which conformably overlies the upper Caradoc–lower Llandovery turbidites of the lower Milliners Arm Formation.

INTRODUCTION AND REVIEW

In the Exploits Subzone, polymictic, marine conglomerates conformably overlie and interfinger with the upper Caradoc–(?)Llandovery turbiditic sequences of the Point Leamington Formation (e.g., Dean, 1978; Colman-Sadd *et al.*, 1992b). The Point Leamington Formation has been introduced by Williams (1991) in place of the Point Leamington Greywacke of the upper Exploits Group, which was originally defined by Helwig (1967, 1969) and Horne and Helwig (1969). Williams (1991) has incorporated into the Point Leamington Formation, turbiditic deposits of the Sansom Greywacke (e.g., Heyl, 1936; Helwig, 1969) and the latter name has automatically been abandoned. The Point Leamington Formation corresponds to the upper Caradoc–lower Llandovery deposits of the Milliners Arm Formation from New World Island (McKerrow and Cocks, 1978; Watson, 1981) and the Gull Island Formation from Badger Bay (Nelson, 1979).

The post Point Leamington conglomerates have been referred to in the literature as 'Goldson Formation' (e.g., Twenhofel and Shrock, 1937; Helwig, 1969; Dean, 1978; Arnott, 1983a,b; Arnott *et al.*, 1985), 'Goldson Group' (Kay, 1969; McKerrow and Cocks, 1978; Watson, 1981) and 'Goldson Conglomerate' (O'Brien, 1990, 1991a). Originally, the term 'Goldson formation' was introduced by Twenhofel and Shrock (1937) for the succession of conglomerate-dominated deposits that outcrop around Goshens (formerly Goldson) Arm on New World Island. Williams (1963) and Kay (1969) expanded the Goldson formation to embrace all conglomerates on New World Island under the name 'Goldson Group', including the conglomeratic, upper part of the Milliners Arm Formation. Helwig (1967, 1969), Dean (1978), Pickering (1987), O'Brien (1990, 1991a), Williams (1991) and Colman-Sadd *et al.* (1992b) extended the term 'Goldson' even further, incorporating all conglomeratic rocks that overlie and interfinger with the Upper Ordovician turbidites of the Point Leamington Formation, including the conglomerates in the Point Leamington area.

McKerrow and Cocks (1978) restricted the Goldson Group to the paleontologically documented upper Llandovery formations that are younger than the Big Muddy Cove Formation (see Figure 3); the latter being probably an equivalent of the upper portion of the Milliners Arm Formation (Arnott, 1983b). Arnott (1983a,b) and Arnott *et al.* (1985) reintroduced the name 'Goldson Formation' and Arnott (1983b) informally subdivided it into four members, although he never actually published the proposed subdivision. Until sound paleontological, sedimentological

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and provenance controls are established for the so called 'Goldson' conglomerates (particularly for those outside of the type area where more detail work is required), the name 'Goldson Formation' should remain restricted to the type sequences on New World Island (McKerrow and Cocks, 1978; Arnott, 1983a,b; see Figure 3).

This study presents sedimentological, paleontological and provenance data for the polymictic conglomerates in the area of Point Leamington, New Bay (Figures 1 to 3). An alternative correlation with the upper Milliners Arm Formation is proposed in the final section. The term 'Goldson' is abandoned in this report in favour of an informal, local name 'Randels Cove conglomerate' (after Randels Cove in West Arm, Figure 2).

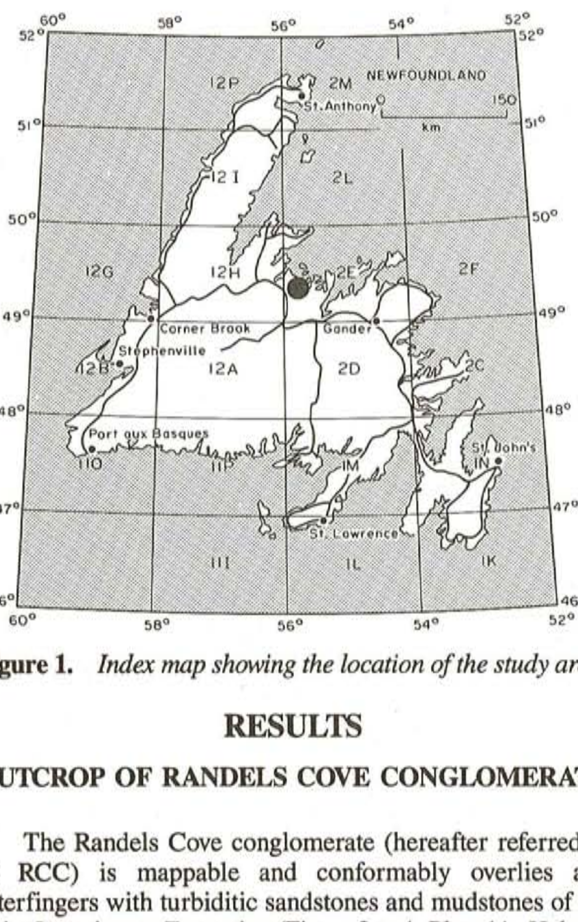

Figure 1. *Index map showing the location of the study area.*

RESULTS

OUTCROP OF RANDELS COVE CONGLOMERATE

The Randels Cove conglomerate (hereafter referred to as RCC) is mappable and conformably overlies and interfingers with turbiditic sandstones and mudstones of the Point Leamington Formation (Figure 2 to 4; Plate 1A; Helwig, 1967; Pickering, 1987; O'Brien, 1990, 1991a, b). The lowest conglomeratic lens is in contact with black shale of the Lawrence Harbour Formation (O'Brien, 1991b; Figure 2 and 3). The RCC outcrops mainly on the peninsulas between Osmonton Arm, West Arm and Southwest Arm in the core of the north-trending syncline (Figure 2), and this main, top horizon of the RCC has a thickness of at least 600 m. The total thickness of the RCC cannot be determined, because of the interfingering of the conglomerates with the Point Leamington Formation and tectonic character of the upper boundary of the RCC with older rocks. North of the study area, polymictic conglomerate of presumed 'Goldson' affinity (referred to as RCC in this report) has been reported from mélange of the Boones Point Complex (Helwig, 1967; 1969; Dean, 1978; Nelson, 1981).

SEDIMENTOLOGY

The RCC is represented by resedimented, mass-flow conglomerates that are locally interbedded with turbiditic sandstones and mudstones (Figure 4). The conglomerates are mainly composed of angular to very well-rounded pebbles with a clast- and/or matrix-supported texture (Plates 1 and 2). The pebble fraction is polymictic, characterized by a predominance of extrabasinal felsic volcanic and plutonic clasts (see next section for details). Abundant mudstone and sandstone rip-up intraclasts are typically much larger than the extrabasinal material and reach up to a few metres in size (Figure 4; Plates 1C and 1D). The average extraclast : intraclast size ratio is around 1:6. Except for a few muddy olistostrome beds (Figure 4B, second column; see also Plate 1C), the matrix is poorly sorted, very coarse-grained sandstone with a negligible amount of clay (Plate 2A).

The well-defined conglomerate beds are mainly structureless and either coarse-tail, normally graded (Figure 4; Plate 1B) or ungraded. The ungraded beds are thicker and coarser grained because of a high proportion of large intraformational rip-up rafts (Plate 1C). The upper portions of some of the normally graded beds show parallel stratification and trough cross-stratification (Figure 4; Plate 1B).

According to Pickering (1987, page 237), the deposits of the RCC accumulated from sediment gravity flows. It is further proposed herein that turbulent-to-laminar debris flows generated the normally graded beds in which the coarsest fraction settled as a result of dumping of turbulence. The ungraded, raft-bearing conglomerates accumulated from cohesive, and mainly laminar, debris flows (e.g., Lowe, 1982; Nemec and Steel, 1984).

The debris flows were often accompanied by high-density turbidity currents, depositing above the coarse, debris-flow beds finer grained and parallel or trough cross-stratified traction deposits (Plate 1B). Massive, sandy granule conglomerates, associated with faint parallel laminations (Plate 2B), probably represent repeated accumulation of traction carpet in response to unsteadiness within high-density turbidity current (Lowe, 1982).

The sharp bases of mass-flow beds are commonly erosional, defining in many places rough scours and channels with depths up to 2 m (Figure 4; Plate 1B). Although Pickering (1987, page 237) reports conglomerate-filled channels cutting through tens of metres of underlying turbiditic deposits of the Point Leamington Formation, the presence of such large-scale erosional features was not confirmed.

The RCC debris-flow conglomerates are interpreted to have formed a gravelly apron that accumulated in deep-water setting beyond the shelf break (Stow, 1985), filling slope-entrenched channels and gullies (Pickering, 1987). Abundant sedimentary rip-up clasts were incorporated by the highly erosional debris-flow events from the dissected slope and basin-plain sediments of the Point Leamington Formation. Orientation of the ab planes of sedimentary rafts from three cohesive debris-flow beds of the main, upper body of RCC (Figure 5; see also Plate 1C), indicates a generally southerly paleoflow, and supports a southerly dipping regional depositional slope as has been inferred for the Point Leamington Formation by Helwig (1967, 1970) and Pickering (1987). The slope and the locus of the RCC mass-flow sedimentation are thought to have been controlled by south-directed thrusts (Nelson, 1981).

CLAST COMPOSITION

The RCC is a polymictic mixture of igneous and sedimentary detritus and there are no significant compositional differences between the main, upper body of RCC and the lower lenses, which occur within the Point Leamington Formation (Figure 3). The sandstone turbidites of the Point Leamington Formation are petrographically very similar to the sand fraction of the RCC.

The RCC contains clasts of rhyolite, dacite, felsic tuff, andesite and basalt. The volcanogenic component is accompanied by clasts of tonalite and granodiorite and less common diabase, diorite and granite (see also Helwig, 1967). There is also a subordinate proportion of siliceous black shale, turquoise celadonitic chert, Fe-stained radiolarite (with strong pre-incorporation compaction fabric) and red jasper. Many volcanic rock fragments show evidence of pre-incorporation K-metasomatism or/and mylonitization.

Most of the sedimentary component is represented by intraformational, rip-up fragments of turbiditic sandstone and mudstone that commonly contain pre-incorporation calcareous nodules (Plate 1C). These clasts concentrate in the coarsest gravel fraction and also include blocks of reef limestone (up to 6 m in size) and presumed co-formational calcarenite and carbonate-cemented conglomerates (Plate 1D). The conglomerate fragments, unlike the host RCC beds, display primary open-framework texture, good sorting (Plate 1D) and are free of rip-up clasts. They contain volcanic and plutonic detritus (including chromite), accompanied by chert and sandstone so that they appear to be compsitionally very similar to the host conglomerate.

The mineralogy of the sand fraction of the RCC reflects the composition of the larger clasts. Monocrystalline (commonly strained) quartz, albitized plagioclase, K-feldspar (commonly microcline, micrographic and granophyric textures) are most abundant. They are accompanied by detrital biotite, muscovite, serpentine, epidote, sphene, zircon, allanite, hornblende, actinolite, arfvedsonite, clinopyroxene, garnet, magnetite, ilmenite, chromite and tourmaline. All these mentioned accessory minerals have also been found in the fragments of calc-arenite and carbonate-cemented conglomerate. The detrital chromites separated from one calcarenite clast (following the procedure of Colman-Sadd *et al.*, 1992a, page 328) range from euhedral crystals and their broken fragments to well-rounded grains; some of them have undergone considerable reworking prior to the deposition in the shallow-marine setting (see next sections for details) and before the subsequent resedimentation on the debris-flow apron of the RCC.

Sand-size fragments of phyllite, schistose polycrystalline quartz, quartz-mica schist, and mylonitized volcanic and plutonic rocks have been identified in thin sections of sandstone. There are also altered fragments of peridotite consisting of serpentine, quartz and calcite, which retain the characteristic mesh texture of serpentinized ultramafic rock. No metamorphic rock fragments of higher than greenschist facies have been found in the RCC. After deposition, the RCC and the Point Leamington Formation were affected by pumpellyite–prehnite facies metamorphism (Pickering, 1987; Franks, 1974, 1976) and contain the typical alteration products.

PALEONTOLOGICAL CONSTRAINTS

The lower horizons of the RCC interfinger with turbidites of the Point Leamington Formation that contain late Caradoc–Ashgill graptolites (Williams, 1991; Williams *et al.*, 1992). The only fossils that have been found within the RCC occur as clasts or in fragments of limestone and calcarenite. Helwig (1967, page 76) and Dean (1978, page 137) mentioned brachiopods, corals and trilobites of Llandovery age, but gave no identifications. Arnott *et al.* (1985, page 610) collected more corals, and questioned the Silurian age of the RCC, based on these specimens. In this study, crinoids, the alga *Girvanella* and conodonts have also been found in the RCC limestone clasts.

Most of the macrofossils found in the top, main body of the RCC have yet to be positively identified, including many of the solitary and colonial corals from debris-flow deposits in the sections at Randels Cove (Figures 2 and 4) and on Big Island. However, the following have been provisionally identified:

Anthozoa-Rugosa

- *?Densigrewingkia* sp. undet.
- *Streptelasma* sp. cf. *S. rusticum* (Billings, 1866)

Anthozoa-Tabulata

- *Favosites* sp. undet.
- *Halysites catenularis* (Linné, 1767)
- *Halysites* sp. undet.

Streptelasma rusticum (Billings, 1866) is restricted to the (latest Ordovician) Richmondian Stage of the Cincinnatian Series; Twenhofel (1928, page 113) reports *Streptelasma* sp. cf. *S. rusticum* (Billings, 1866) from the Richmondian Vauréal Formation of Anticosti Island. *Halysites catenularis* (Linné, 1767) ranges from the Late Ordovician to the Early Devonian and has a wide distribution throughout the Silurian of North America and Europe (Shimer and Shrock, 1944, page 113). It occurs in the Vauréal, Ellis Bay, Bescie, Gun River, Jupiter and Chicotte formations of Anticosti Island (Twenhofel, 1928; Bolton, 1972); these formations span an interval from (latest Ordovician) Richmondian to Llandovery C_6 (latest Telychian) or earliest Wenlock (Bolton, 1972; Barnes, 1989, page 102,

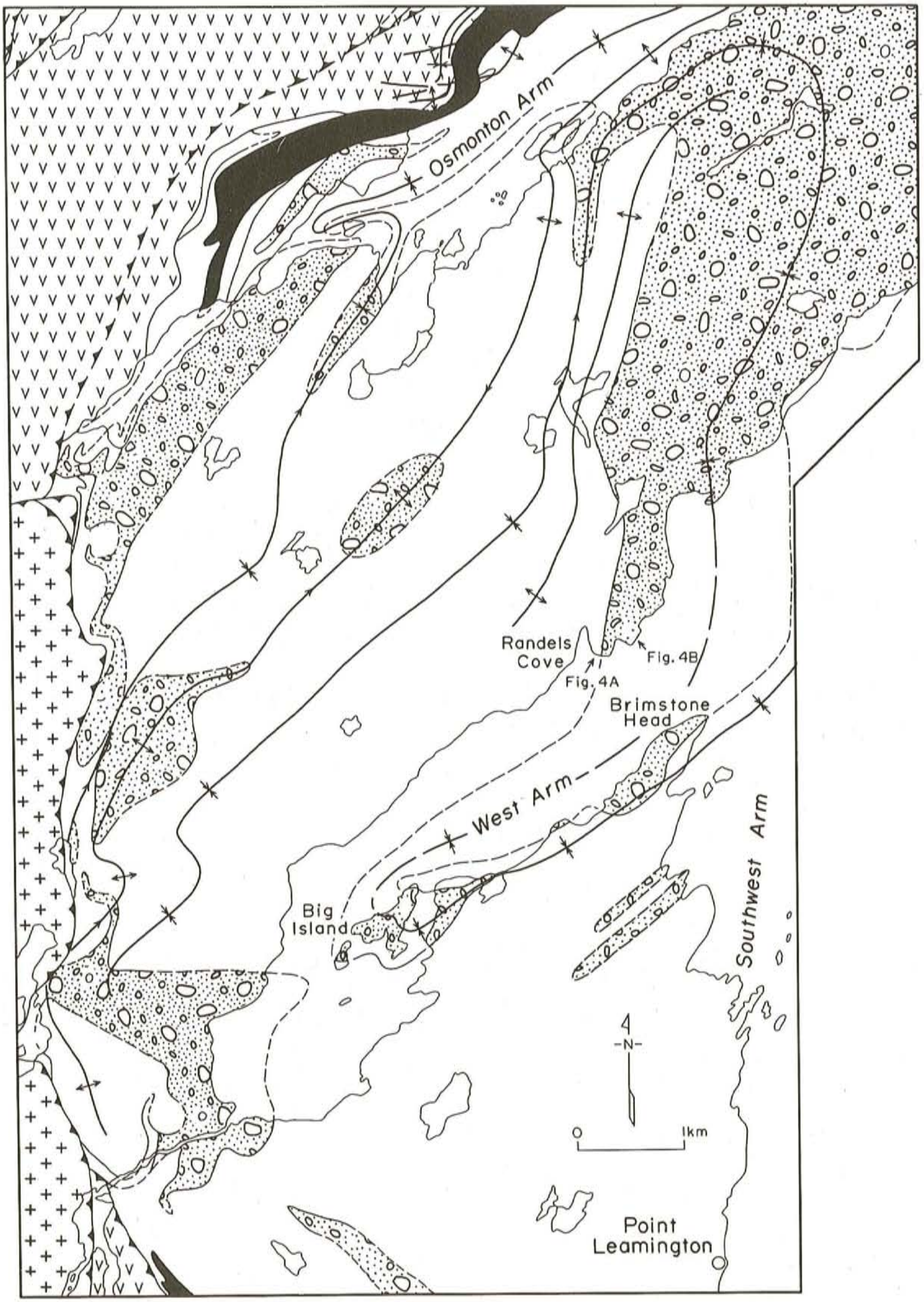

Figure 2. *Geological map of the Point Leamington area (compiled from Open File maps by O'Brien, 1990, 1991).*

LEGEND (for Figure 2)

UPPER ORDOVICIAN – ?LOWER SILURIAN

RANDELS COVE CONGLOMERATE (former "Goldson Formation")

polymictic pebble conglomerate

POINT LEAMINGTON FORMATION

turbiditic sandstone and mudstone

LAWRENCE HARBOUR FORMATION

black shale and minor chert

MIDDLE ORDOVICIAN

WILD BIGHT GROUP

pillow basalt; breccia; tuff; volcaniclastic sandstone and chert

LOWER – MIDDLE ORDOVICIAN

SOUTH LAKE IGNEOUS COMPLEX

unseparated tonalite and quartz diorite; mafic dykes; ophiolitic metagabbro

KEY

geological boundary (defined, approximate)..............

anticline..

syncline..

fold axial trace (plunge direction indicated)..............

thrust fault (barbs on upthrown side).........................

Figure 74). Northrop (1939) also reports *Halysites catenularius* (Linné, 1767) from the Clemville, La Vieille, Gascons, Bouleaux, West Point and Indian Point formations of Gaspé (Québec), spanning an interval of Llandovery C_1 (latest Aeronian) to Ludlow (Berry and Boucot, 1970).

Four limestone clasts have yielded conodonts that are known to range from the Caradoc to the Ashgill (Table 1). Sample TD-91-24 contains *Gamachignathus hastatus*, which represents latest Ordovician Fauna 13 (post-Richmondian; McCracken *et al.*, 1980; Barnes, 1989) and has been described from the platformal strata of Anticosti Island, on the North American continental margin (McCracken *et al.*, 1980). Sample TD-91-12 contains one M-element of the genus *Ozarkodina*, which may be Llandovery in age. It is noteworthy that limestone blocks from the Boones Point Complex have yielded Llanvirn–Llandeilo conodonts (Nelson, 1981).

PROVENANCE

The RCC is a product of mass-flow resedimentation of polycyclic gravels. Fragments of calcarenite and polymictic conglomerate indicate that a certain proportion, if not all, of volcanic and plutonic (including ophiolitic) detritus as well as chert and black shale debris have been recycled from shallow-marine clastic formations. The conodont fauna from the fragments of the presumed coeval limestones suggests a Late Ordovician–(?) Early Silurian age for these source sediments. The inferred shelf clastic formations and contemporaneous reef carbonates fringed the continental margins around the Iapetus Ocean and supplied detritus for the deeper areas of the basin. A substantial volume of the RCC debris was also derived from the entrenched, deep-water turbiditic deposits of the Point Leamington Formation. A major Late Ordovician regression, possibly related to continental glaciation in North America (e.g., McCann and Kennedy, 1974; Allen, 1975; McCracken *et al.*, 1980), may have exposed the shelf sediments to reworking and resedimentation beyond the shelf break (Piper, 1987).

Taking into account the destructive character of the Upper Ordovician–Lower Silurian North American continental margin, the volcanic and plutonic detritus of the RCC had most likely originated in accreted and deeply dissected, Upper Cambrian–Lower Ordovician magmatic arc and ophiolite complexes (Helwig, 1967; Nelson, 1981; see also Colman-Sadd *et al.*, 1992b). These ultimate sediment sources may be represented today by units of Exploits Subzone (Williams *et al.*, 1988), such as Wild Bight and Exploits groups, South Lake Igneous Complex and Pipestone Pond Complex (Swinden *et al.*, 1990; Dec *et al.*, 1992; O'Brien, 1992; Colman-Sadd *et al.*, 1992a). The igneous (including ophiolitic) and sedimentary siliceous debris was probably also derived from accreted remnants of back-arc basins (e.g., upper Wild Bight Group, Strong Island Chert, Lawrence Harbour Formation; Swinden *et al.*, 1990; Dec *et al.*, 1992).

The previous workers have favoured the volcano-sedimentary and ophiolitic rocks of the Notre Dame Subzone (Williams *et al.*, 1988) as the source of sediment in the outcropping to the south (south of the Red Indian Line) Goldson, Point Leamington and Milliners Arm formations (Helwig and Sarpi, 1969; Dean, 1978; Nelson, 1981; Nelson and Casey, 1979; Watson, 1981; Arnott, 1983a). Although this northern provenance has been supported by palaeocurrents (Helwig, 1967; Watson, 1981; Arnott, 1983a; Arnott *et al.*, 1985; see also Nelson, 1981), it is clear that the polymictic composition of the Upper Ordovician–Lower Silurian sediments also matches very well the rocks of the Exploits Subzone (Colman-Sadd *et al.*, 1992b, page 585). Helwig (1967, page 72) speculated that both the Exploits and Notre Dame subzones (Wild Bight and Lushes Bight groups respectively) may have shed the volcanic and chert debris into the RCC. Llanvirn–Llandeilo limestone clasts with conodonts similar to those in the Cobbs Arm limestone (Exploits Subzone) have been reported from the Bonnes Point Complex (Nelson, 1981); Nelson (1981) has inferred also that the Roberts Arm Group (Notre Dame Subzone) was the most likely source of the accompanying mafic volcanic detritus.

The age and geochemical signatures of many of the presumed sediment sources in the Notre Dame Subzone (e.g., Cottrells Cove and Moretons Harbour groups) remain unknown. Furthermore, there is lack of any such data for

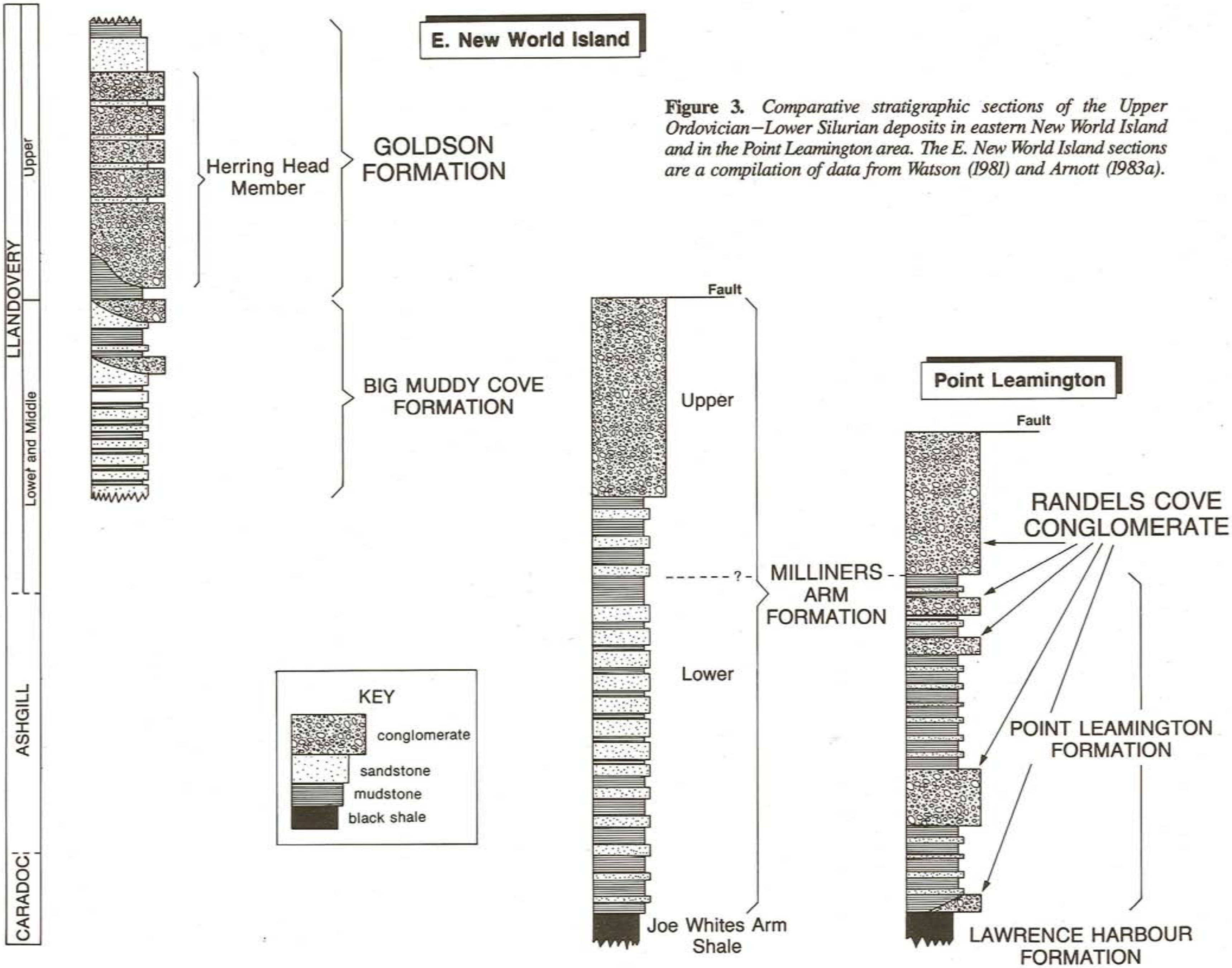

Figure 3. *Comparative stratigraphic sections of the Upper Ordovician–Lower Silurian deposits in eastern New World Island and in the Point Leamington area. The E. New World Island sections are a compilation of data from Watson (1981) and Arnott (1983a).*

Table 1. Conodont fauna from limestone clasts, Randels Cove conglomerate

Sample, locality and grid reference	Conodont fauna	Sample age
TD-91-12, Big Island 612900m.E. 5468900m.N.	one M-element of the genus *Ozarkodina*	probably Llandovery
TD-91-24, Randels Cove 615000m.E. 5471700m.N.	*Panderodus gracilis* (Branson and Mehl)	Ashgill
	Gamachignathus hastatus (McCracken, Nowland and Barner)	*G. hastatus* is restricted to latest Ordovician, Fauna 13 (post Richmondian)
	Drepanoistodus suberectus (Branson and Mehl)	
TD-91-77, Big Island 612900m.E. 5468900m.N.	*Protopanderodus liripiptus* (Kennedy *et al.*)	
	Drepanoistodus suberectus (Branson and Mehl)	Caradoc–Ashgill
	?Hamerodus europaeus (Serpagli)	
	Scabadella altipes (Henningsmoen)	
TD-91-78, Big Island 612900m.E. 5468900m.N.	*Protopanderodus* sp.	Upper Ordovician

clasts from the discussed conglomerates. Clearly, unless this information is available, specific aspects of sediment provenance cannot be adequately addressed.

CONCLUSIONS

The Goldson Formation in the type area on New World Island formed in a shallow-marine setting (McKerrow and Cocks, 1978) and, according to Arnott (1983b) and Arnott *et al.* (1985), the hallmark Goldson polymictic conglomerates represent a mass-flow-dominated, subaqueous fan delta. The conglomerates are interbedded with shelf siltstones and sandstones that contain late Llandovery brachiopods (McKerrow and Cocks, 1978; Arnott *et al.*, 1985). The Goldson Formation is far more heterogeneous in terms of clast composition than the RCC and contains a unique subunit of red conglomerate, which is dominated by basalt, diabase and gabbro clasts (Helwig and Sarpi, 1969; Arnott, 1983a).

Although the clast composition of the main (Herring Head) member of the Goldson Formation from New World Island (Figure 3) is generally very similar to that of the RCC (Arnott, 1983a; Helwig and Sarpi, 1969), the Ashgill–(?)Llandovery age of the RCC together with its interfingering relationship with the deep-water turbidites of the Point Leamington Formation are incompatible with the 'Goldson' stratigraphic affinity. The present authors suggest that a correlation of the RCC with the upper, conglomeratic part of the Milliners Arm Formation (Figure 3; Watson, 1981) appears far more justified. The latter deep-sea fan deposits, like the debris-flow apron of the RCC, conformably overlie upper Caradoc–lower Llandovery turbidites of the lower Milliners Arm Formation (the partial equivalent of the Point Leamington Formation) and their polymictic, yet homogeneous throughout, clast composition is very similar to that of the RCC (Helwig, 1969; Watson, 1981). In the future, the RCC should be probably granted the formal member status and thus the 'Randels Cove Member' would constitute a subunit of the Point Leamington Foramtion.

The detritus of the RCC has been recycled from shallow-marine, siliciclastic–carbonate formations, although it had ultimately originated in a presumed Upper Cambrian–Lower Ordovician composite source of dissected magmatic arc complexes, obducted ophiolites and accreted back-arc volcano-sedimentary formations. Abundant intraformational sedimentary debris has been derived from the entrenched turbiditic deposits of the Point Leamington Formation.

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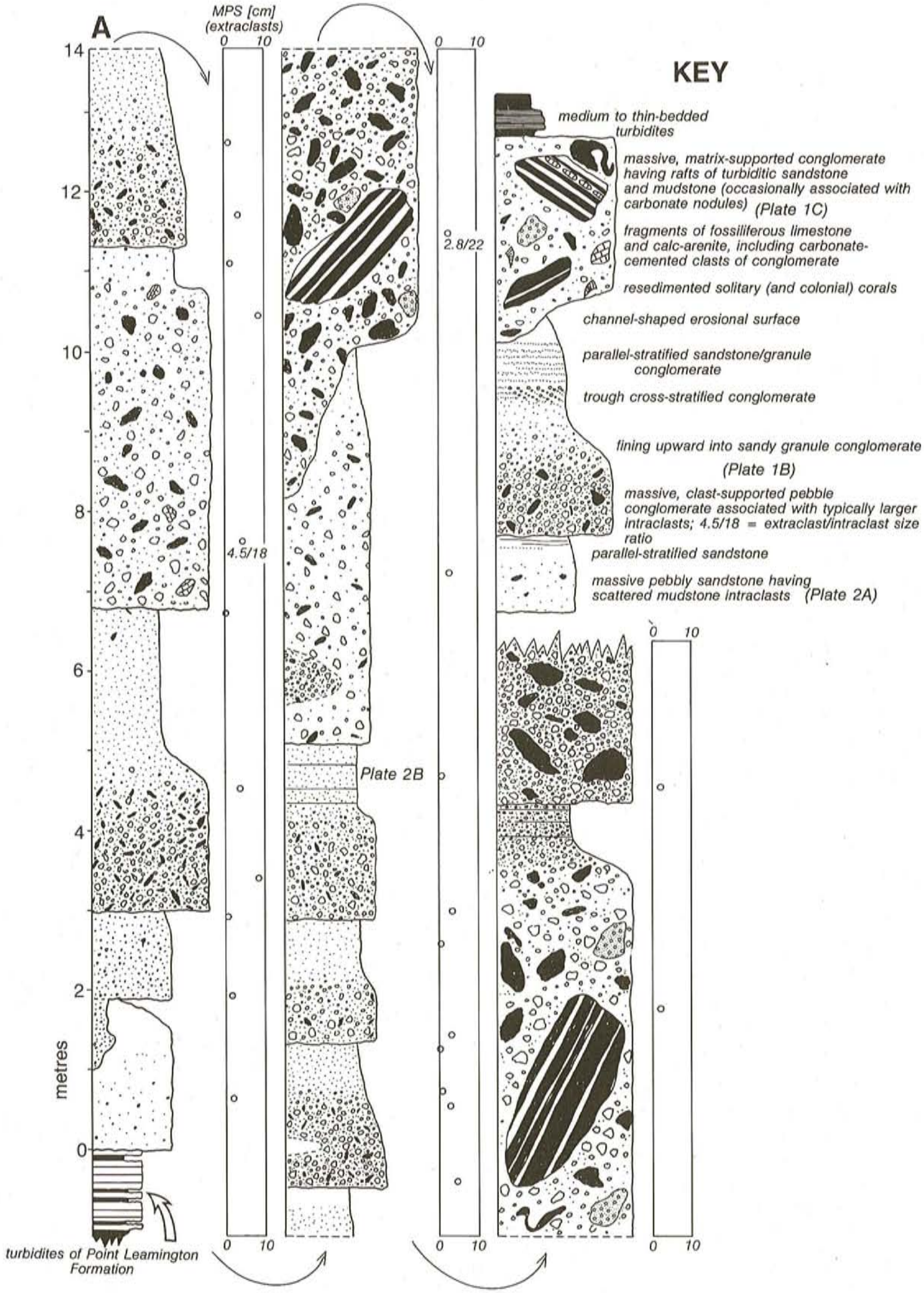

Figure 4. *(A) and (B): Representative sections from the Randels Cove conglomerate are dominated by a variety of debris-flow deposits. Both logs have been measured at Randels Cove (see Figure 2), directly above the contact with the turbidites of the Point Leamington Formation. MPS = the maximum particle size (the average of ten largest particles per 1 m²). Structural and textural details of the mass-flow conglomerates are shown in Plates 1 and 2.*

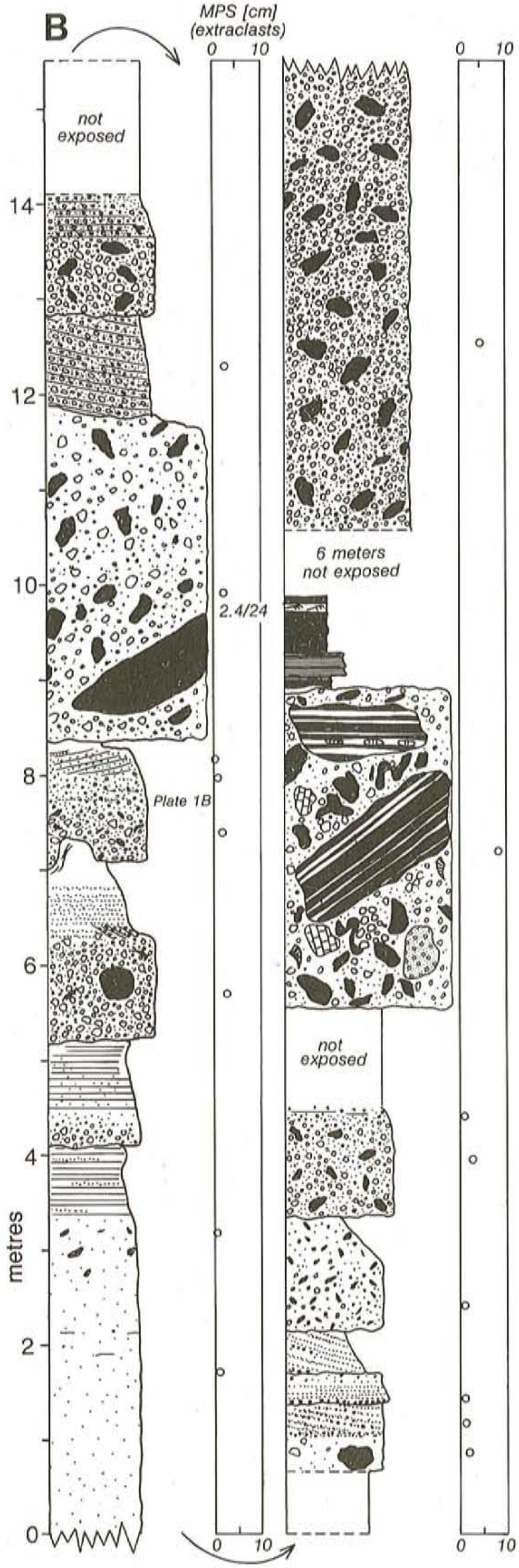

Figure 4. *Continued.*

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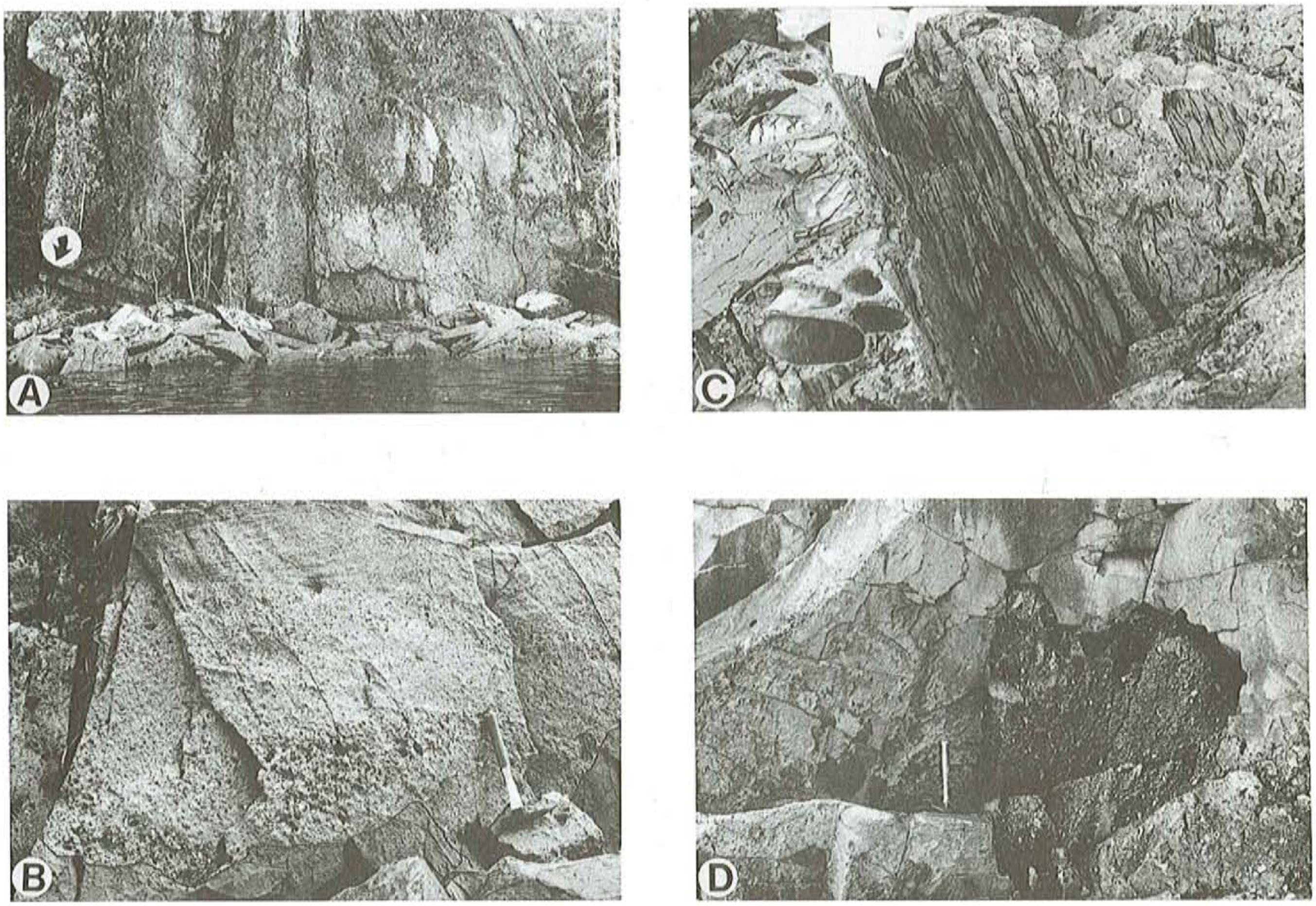

Plate 1. *(A) Massive RCC conformably overlies turbidites of the Point Leamington Formation. The arrow points to the sharp (mapable) erosional contact; the white scale above is 2 m long. Location: small island SW off Big Island; (B) normally graded debris-flow conglomerate passing into trough cross-stratified traction deposits of high-density turbidity current; note rough erosional base of the mass-flow bed (outlined in black). Location: Randels Cove (see also Figure 4A); (C) Cohesive debris-flow conglomerate containing abundant mudstone—sandstone rafts and resedimented carbonate nodules, all most likely derived from the Point Leamington Formation (lens cap for scale). Location: 2 km north of Randels Cove; (D) Angular boulder of well-sorted, carbonate-cemented conglomerate enclosed in RCC mass-flow conglomerate. Location: Brimstone Head (Figure 2).*

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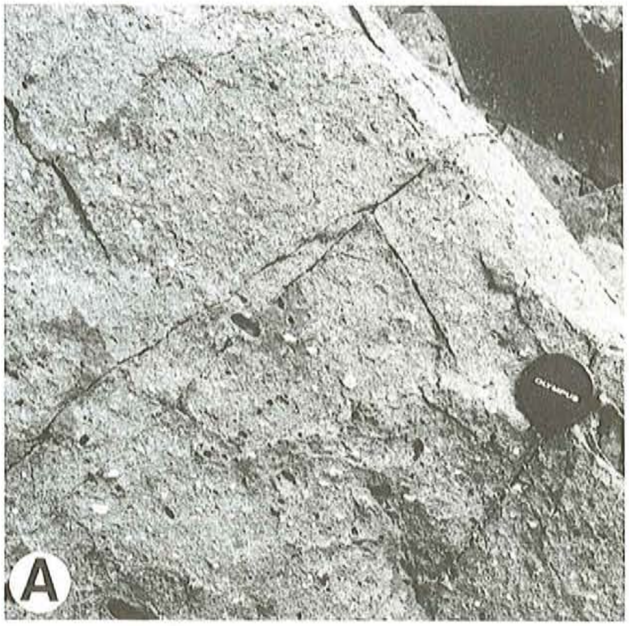

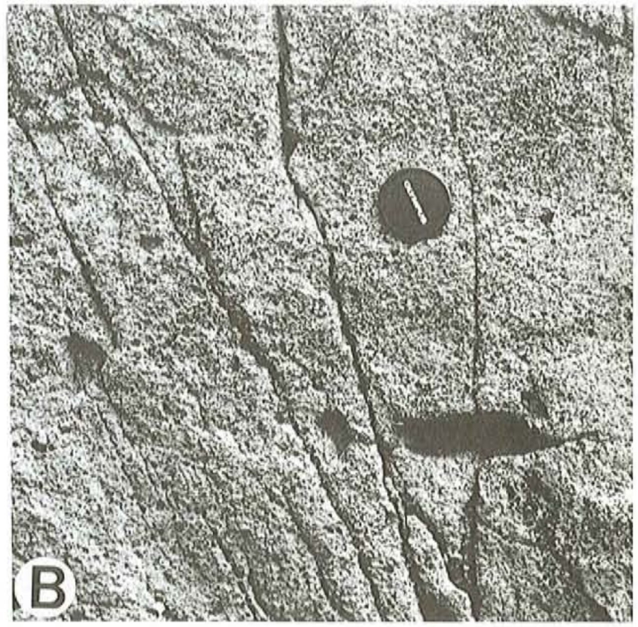

Plate 2. *(A) Matrix-supported, cohesive debris-flow conglomerate; (B) Clast-supported, massive and faintly parallel-stratified deposit of traction carpet, formed during emplacement of high-density turbidite (see Figure 4A). Location of both photographs: Randels Cove.*

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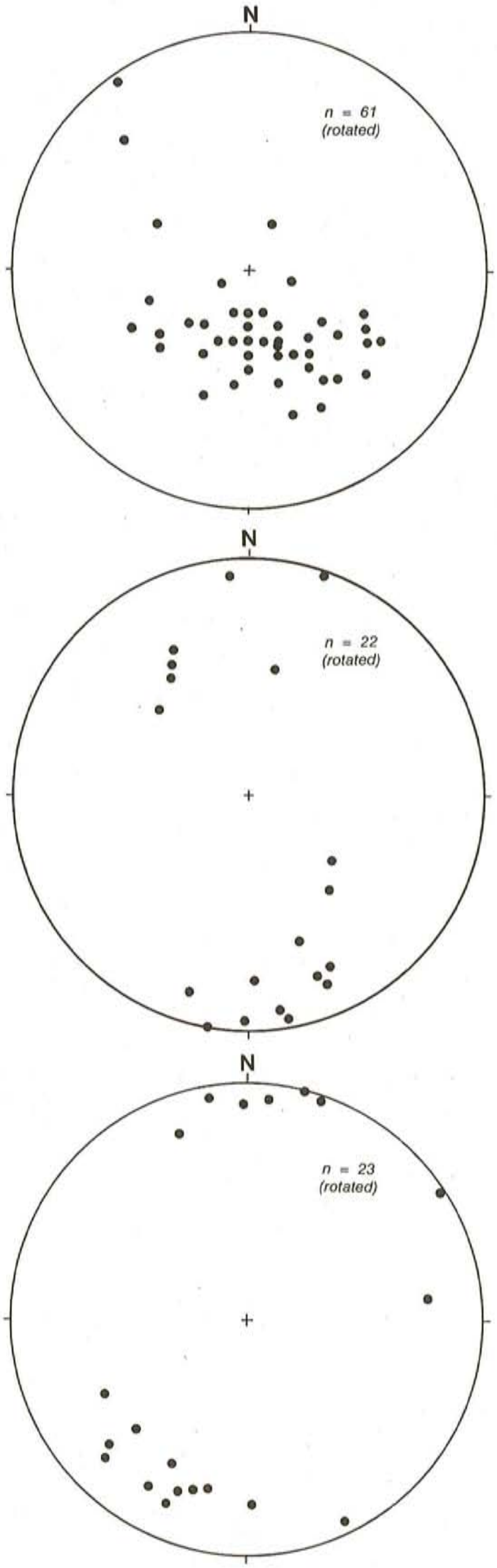

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Figure 5. *Orientation of ab planes of sedimentary rafts in three debris-flow beds (see also Plate 1C). The orientation is consistent with the southwart-dipping slope of the sedimentary basin (Pickering, 1987). The points represent lower hemispherical equal area projections of poles to ab planes.*

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