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PRELIMINARY FINDINGS ON THE GEOLOGY OF THE TRINITY MAP AREA (NTS 2C/06), NEWFOUNDLAND

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ABSTRACT

Completion of the second year (NTS 2C/06) of a two-year program to map the Bonavista Peninsula at a 1:50 000 scale has confirmed the juxtaposition of the Bonavista and St. John's basins along the Spillars Cove–English Harbour Fault. The Big Head and Rocky Harbour formations occupy most of the Trinity map area to the west of the basin-bounding fault, while the uppermost Conception and lowermost Signal Hill groups are found to the east of the fault. A revision of the stratigraphy of the Rocky Harbour Formation, Musgravetown Group, includes the addition of two new facies; the volcaniclastic Herring Cove facies and a new Neoproterozoic glacial event on the Avalon Peninsula, the Trinity facies.

The truncation of the thick succession of St. John's and Conception Group sedimentary rocks found in the Bonavista (map) area by the Spillars Cove–English Harbour Fault in the Trinity (map) area, effectively removes the fossiliferous Conception Group and confirms the division of the Bonavista Peninsula into two unique Neoproterozoic depositional basins.

The current understanding of the Rocky Harbour Formation stratigraphy on the Bonavista Peninsula indicates a complex interfingering and lateral variation of facies, further complicated by northeast-directed thrusting and a transgressive glacial deposit, prograding across multiple facies in the upper Rocky Harbour Formation. In ascending order, the general facies succession of the Rocky Harbour Formation in the Trinity (map) area is Plate Cove, Monk Bay, Cape Bonavista, Kings Cove Lighthouse, Trinity (new), Herring Cove (new) and Kings Cove North facies. Apparent onlapping of the Big Head Formation by the Rocky Harbour Formation has truncated the Amherst Cove and Birchy Cove facies of the Rocky Harbour Formation within the Trinity map area. Both new facies have been mapped for over 20 km from north to south across the central portion of the map area. The Trinity facies is an unequivocal glaciomarine, matrix-supported, dropstone diamictite with convincing evidence of glaciation including striated and faceted clasts, and dropstones. Volcanic tuffs, peperites and rhyolite sills of the Herring Cove facies evoke a rapid change in depositional environments as de-glaciation coincided with renewed volcanism.

Facies associations, lithology variations and previous stratigraphic relationships in the Avalon Zone prevent direct correlation of the Trinity facies to the well known Gaskiers Formation suggesting a new, possibly younger Ediacaran glacial event for the Avalon Zone in Newfoundland.

INTRODUCTION

Detailed bedrock mapping of southern Bonavista Peninsula (2C/06) was completed during the 2010 summer field season (Figure 1). This report summarizes the second-year findings of a 1:50 000-scale mapping project on the Bonavista Peninsula, following on from work in the northern Bonavista Peninsula (Normore, 2010). The map area was surveyed by boat along the coastline and the interior was accessed *via* foot, ATV trails and resource roads.

Field work concentrated on mapping the southern portion of the Bonavista Peninsula with the following aims: 1) to strengthen the internal stratigraphy of the Musgravetown Group, and 2) to refine the relationship of the Musgravetown Group to the Conception, St. John's and Signal Hill groups located to the east, across the Spillars Cove–English Harbour Fault.

Previous regional studies assigned sedimentary rocks of the Musgravetown Group to the entire Bonavista Peninsula (Hayes, 1948), and later divided into the Bull Arm, Rocky Harbour and Crown Hill formations by Jenness (1963). O'Brien and King, (2002) proposed separating the Bonavista Peninsula into two distinct sedimentary basins represented by the Musgravetown Group on the west and the Conception, St. John's and Signal Hill groups on the east. The Musgravetown Group has since been subdivided in the

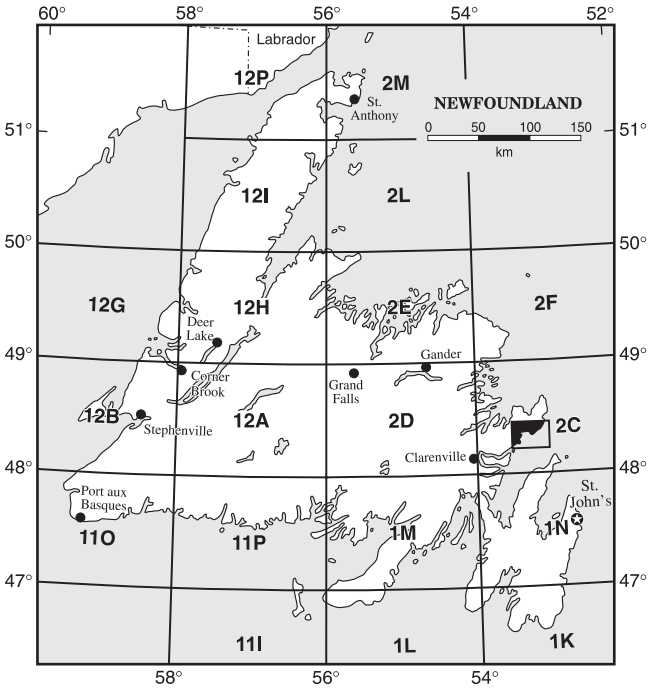

Figure 1. *Location map of the study area (NTS 2C/06).*

map area into the Bull Arm, Big Head, Rocky Harbour and Crown Hill formations (Normore, 2010). Further refinement of facies within the Rocky Harbour and Crown Hill formations is found in O'Brien and King (2002, 2005) and Normore (2010).

LOCATION, ACCESS AND PHYSIOGRAPHY

The Bonavista Peninsula is located in eastern Newfoundland between Bonavista Bay, to the northwest, and Trinity Bay, to the southeast; the peninsula lies within the Avalon Zone of Williams (1979). The Trinity map area (NTS 2C/06) lies immediately south of the Bonavista map area (NTS 2C/11; Normore, 2010) and is 62 km northeast of Clarenville *via* routes 230 and 235. The area has a good network of paved roads, four resource roads (Plate Cove, Northwest Pond, Carys Pond and World Pond resource roads), an abandoned railway line, and several ATV trails. The topographic relief is gentle having a maximum elevation of 200 m. Bog and barrens dominate the eastern half of the map area. Evidence of extensive glaciation during the last, late Wisconsinian, glacial period (Jenness, 1963; Batterson and Taylor, 2001) is clear throughout the higher elevations on the interior of the map area.

GEOLOGY OF THE TRINITY MAP AREA

The geology of the Trinity map area (Figure 2) consists primarily of folded and thrust-faulted, sedimentary and volcanic rocks of the Bull Arm, Big Head and Rocky Harbour formations representing the Bonavista Basin (Figure 3). These rocks outcrop along the coast, from the southwest corner of the map area to the east side of Robinhood Bay, east to English Harbour and northeast to the northern extent of the map area bounded by the Spillars Cove–English Harbour Fault. To the east of this major fault, outcropping along the west coast of Trinity Bay, a coarsening-upward succession of gently folded sedimentary rocks includes the Trepassey, Fermeuse, Renews Head and Gibbet Hill formations.

NEOPROTEROZOIC BONAVISTA BASIN

MUSGRAVETOWN GROUP

The Musgravetown Group is well exposed along the coastline between English Harbour and British Harbour and outcrops sporadically throughout the interior, north to the boundary with the Bonavista map area. A large area in the north-central part of the Trinity map area has been mapped as the Big Head Formation, unconformably underlying the Rocky Harbour Formation (Figure 2). Limited outcrop, due to extensive bog lands, hindered mapping in this area but sufficient detail was obtained along the railroad to supplement map relationships already known in the Bonavista map area (Normore, 2010). The Rocky Harbour Formation occupies most of the Trinity map area west of the Robinhood Bay Fault and is truncated by the Spillars Cove–English Harbour Fault in the eastern portion of the map area. A small uplifted fault block of Bull Arm Formation volcanic rocks outcrop in the southwestern corner of the map area.

Bull Arm Formation

Intermediate to felsic, porphyritic (Plate 1) and brecciated, calc-alkaline volcanic rocks outcrop in the southwestern corner of the Trinity map area. These rocks are assigned to the Bull Arm Formation and have been uplifted to lie adjacent to the overlying Rocky Harbour Formation (Plate 2). A 2-km-wide belt of bimodal volcanic rocks, identified 1 km to the west of the northwest corner of the Trinity map area (O'Brien, 1994), may be a northern extension of these volcanic rocks.

Big Head Formation

The Big Head Formation consists of grey thin-laminated siltstones interbedded with fine-grained sandstones. It is poorly exposed in the north-central portion of the Trinity map area and is bounded to the west by the Robinhood Bay Fault and the Trinity Pond Fault in the north. It is unconformably onlapped by the upper Rocky Harbour Formation to the east (Figures 2 and 3).

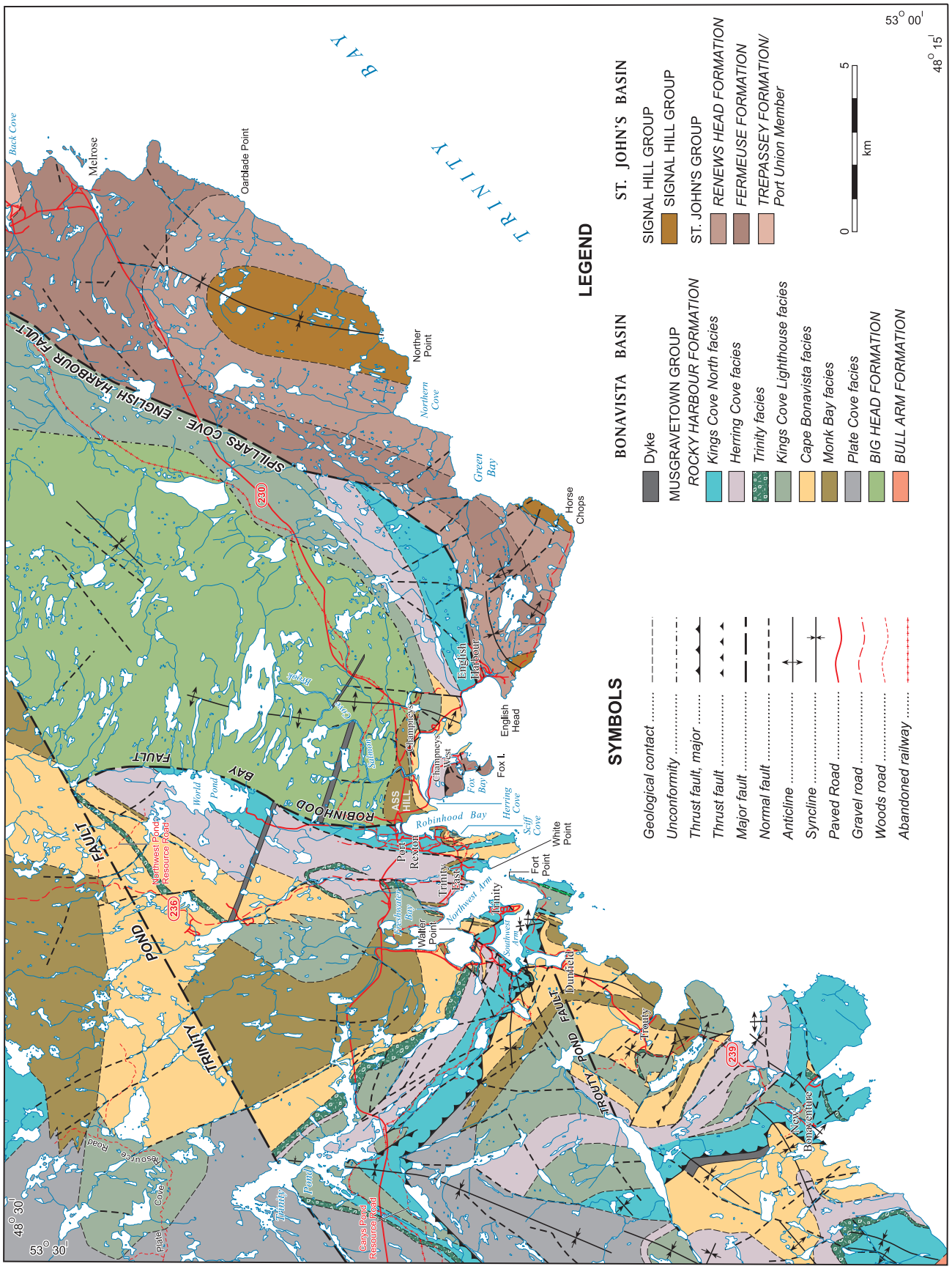

Figure 2. *Geology of the Trinity map sheet (NTS 2C/06).*

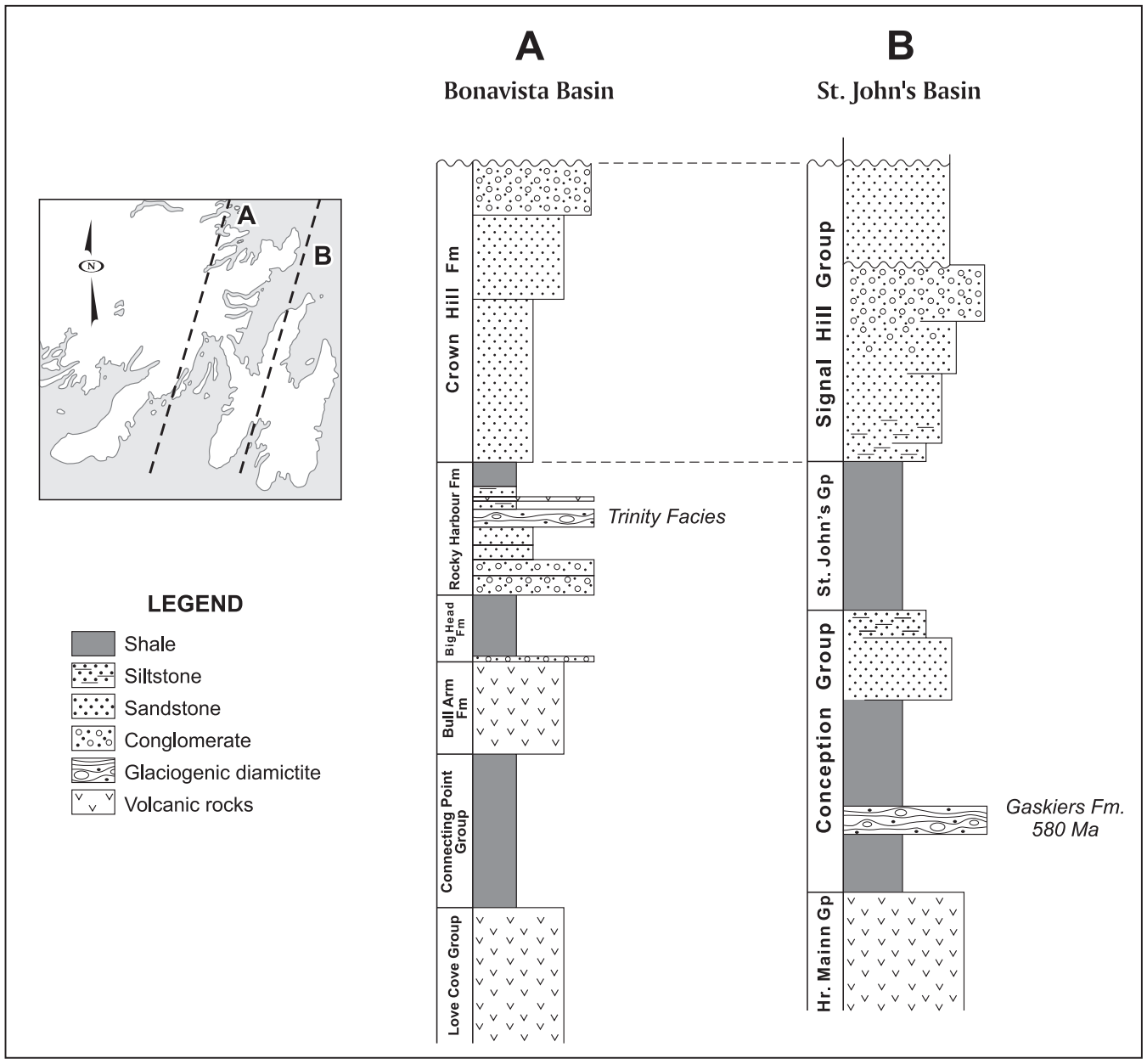

Figure 3. *Simplified stratigraphic sections for areas A (Bonavista Basin) and B (St. John's Basin) on the inset map, Avalon Zone, Newfoundland. The Trinity facies occurs much higher in the Avalon Zone stratigraphy, suggesting a younger Neoproterozoic glaciation, than the well known Gaskiers glaciation, modified from Myrow (1995).*

Rocky Harbour Formation

The Rocky Harbour Formation comprises a succession of broadly folded, sedimentary and volcanic rocks occupying much of the western half of the map area (Figures 2 and 3). This report modifies the previous lithostratigraphic subdivision of the Rocky Harbour Formation on the Bonavista Peninsula (O'Brien and King, 2002; Normore, 2010). In ascending order, the Rocky Harbour Formation in the Trinity map area consists of the following facies; Plate Cove, Monk Bay, Cape Bonavista, Kings Cove Lighthouse, Trinity (new), Herring Cove (new) and Kings Cove North (Figure 4). Lateral facies changes and facies interfingering provide localized irregularities in stratigraphy, which will be addressed in the description of each facies section below.

Although the base of the Rocky Harbour Formation is not exposed in the map area, an onlapping unconformity is postulated based on stratigraphic mapping of the Monk Bay and Kings Cove Lighthouse facies above the Big Head Formation from southwest to northeast in the region north and west of Champney's (Figures 2 and 4). This also accounts

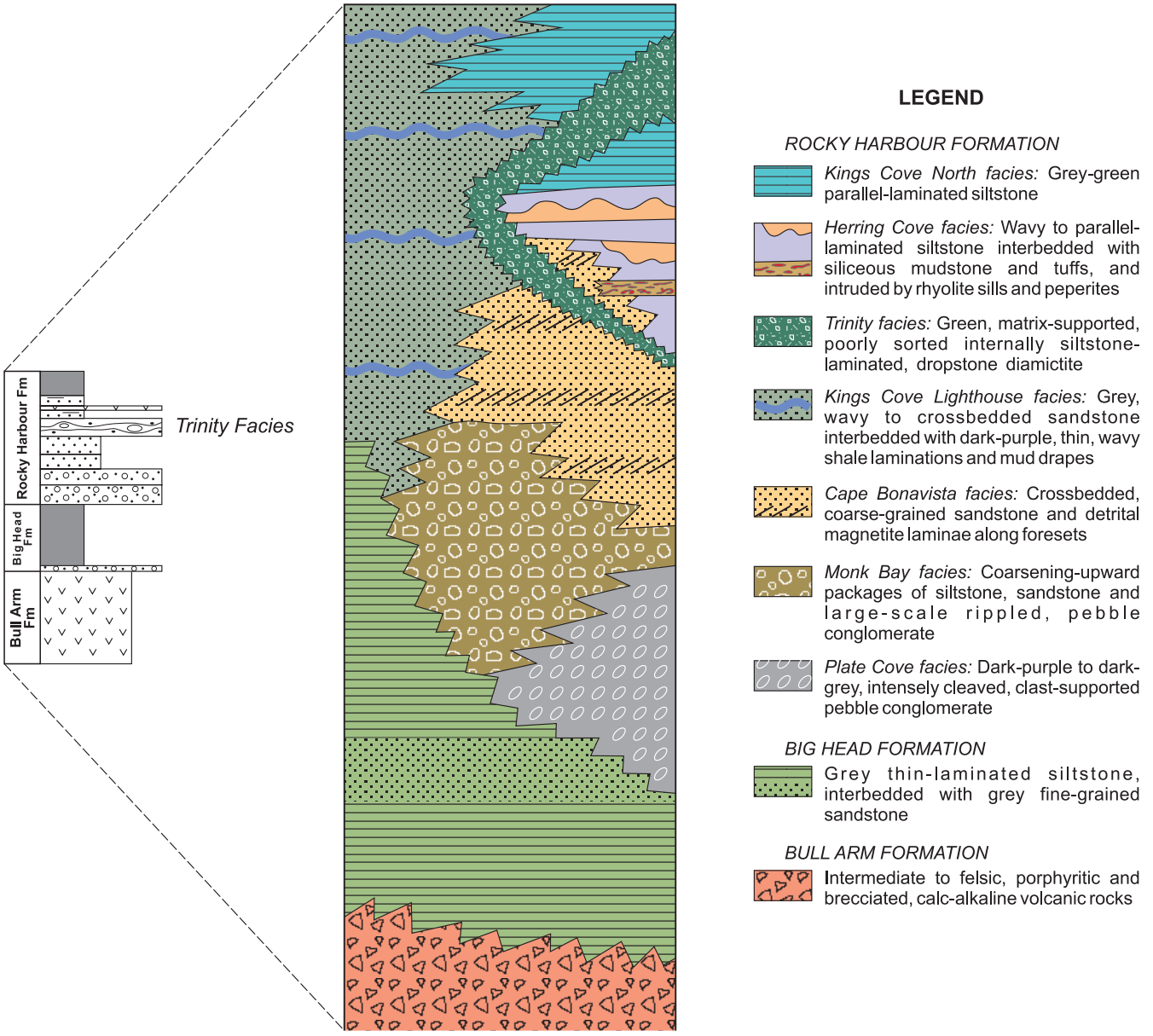

Figure 4. *Schematic stratigraphic log of the facies relationships within the Rocky Harbour, Big Head and Bull Arm formations in the Trinity map area (NTS 2C/06).*

for the absence of the Amherst Cove and Birchy Cove facies present in the Bonavista map area. The upper contact of the Rocky Harbour Formation in the map area is with the Spillars Cove–English Harbour Fault. No Crown Hill equivalent rocks were mapped in the Trinity map area.

Plate Cove Facies

Dark-purple to dark-grey, intensely cleaved, clast-supported pebble conglomerate (Plate 3) of the Plate Cove facies outcrop in three wedge-shaped areas on the western limits of the Trinity map area. This facies is a distinct conglomeratic unit containing abundant dark-purple volcanic clasts that have undergone intense shear strain due to proximity of the Indian Arm Fault, immediately west of the map area. The tectonized Plate Cove facies underlies and, in places, grades laterally into the Monk Cove facies (Figure 4). The lower boundary is not recognized in the Trinity map area.

Monk Bay Facies

The Monk Bay facies is easily recognizable within the Trinity map area due to the distinct coarsening-upward

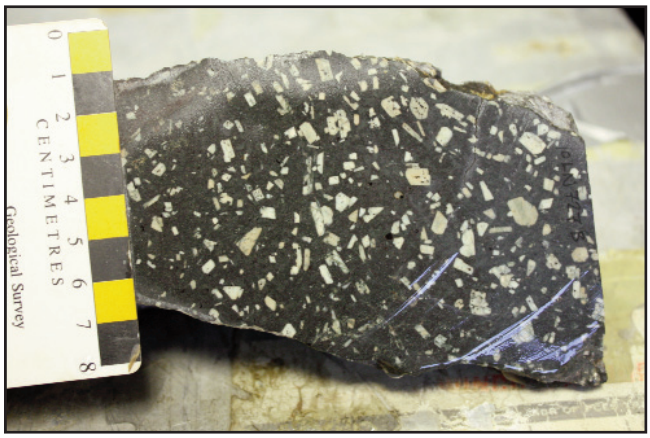

Plate 1. *Intermediate to felsic, porphyritic andesite of the Bull Arm Formation, near the southwest corner of the Trinity map area.*

packages. The sediment packages comprise lower green-grey, thinly laminated rusty siltstone, middle dark-grey, occasionally light-pink, medium- to thick-crossbedded, medium- to coarse-grained sandstone, and a diagnostic large-scale rippled clast-supported pebble conglomerate cap (Plate 4A). Other sedimentary structures include mud drapes, developed in troughs of large coarse-grained ripples (Plate 4B), and both normal- and reverse-graded bedding (Plate 4C). The Monk Bay facies has been observed in three locations; namely, a large southwest-plunging broad anticline mapped along the coast in the bottom of Northwest Trinity Arm and in the interior west of Route 236, a broad open fold to the east of the Robinhood Bay Fault with coastline exposures along the eastern side of Robinhood Bay and lastly in a tight southwesterly plunging anticline between Dunfield and Trouty.

Plate 3. *Purple, thickly bedded, poorly sorted, clast-supported, pebble conglomerate of the Plate Cove facies; pebbles are cleavage aligned; located west of Trinity Pond. Cleavage and bedding marked by white and black lines respectively. Pocket knife is 9 cm long.*

This season's field mapping shows the intercalated nature of the Monk Bay and Cape Bonavista facies' within the Trinity map area (Figure 4). Previous mapping (O'Brien and King, 2002) identified the Cape Bonavista facies near the base of the Rocky Harbour Formation, although a transitional contact between the Cape Bonavista facies and underlying Monk Bay facies has now been established. This transition was previously demarcated as a distinctive upper unit of the Monk Bay facies at Black Bay on the Bonavista map sheet (Normore, 2010).

Cape Bonavista Facies

The most easily recognizable rock type of this facies is the dark green-grey to light pink-grey, crossbedded, medium- to

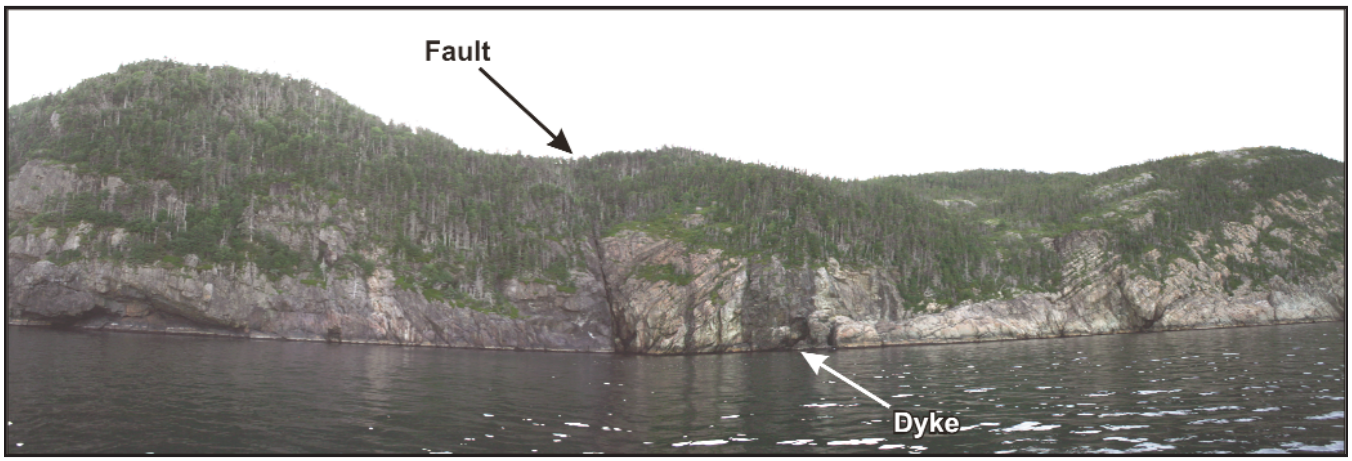

Plate 2. *Faulted contact (black arrow) of the Bull Arm (left) and stratified Rocky Harbour (right) formations near the southwest corner of the Trinity map area. The normal fault, bearing 305˚/80˚N, has considerable vertical throw to bring the Bull Arm Formation adjacent to the Rocky Harbour Formation. Also note dyke (white arrow), 8 m wide by 10 m high, intruding sedimentary rocks to the right of contact.*

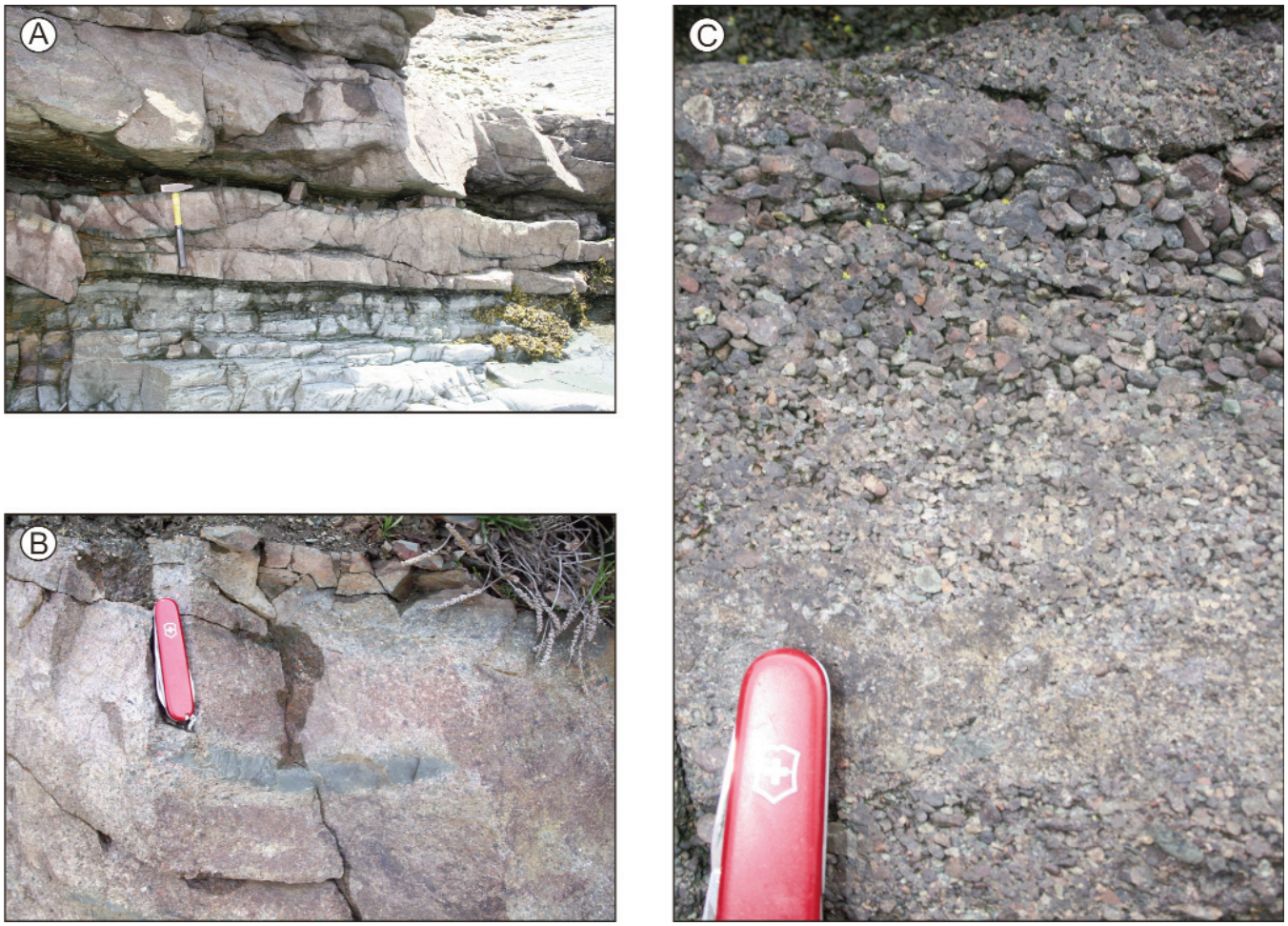

Plate 4. A) *Symmetrical, clast-supported pebble conglomerate wave ripples, wavelength 70 to 85 cm, height 10 to 12 cm, diagnostic of the Monk Bay facies, Robinhood Bay, Trinity Bay. Hammer is 37 cm long.* B) *Mud drapes present within the trough of coarse-grained ripples, deposited during quiescent conditions and preserved between storm beds. Pocket knife is 9 cm long.* C) *Inverse and normal grading of granule to pebble, clast-supported, well-rounded, polymictic conglomerate of the Monk Bay facies, Robinhood Bay, Trinity Bay; slight imbrication of clasts indicate paleoflow from the right. Pocket knife is 9 cm long.*

coarse-grained arkosic sandstones having detrital magnetite laminae along foresets (Plate 5). Sandstone beds are interbedded with black, well-rounded, well-sorted, medium-bedded, granule to pebble conglomerate. Sandstone channels are also locally developed with imbricated angular to subrounded siltstone clast, pebble to cobble conglomerate.

The Cape Bonavista facies in the Trinity map area generally overlies but can interfinger at the base with the Monk Bay facies, and is laterally transitional with the Kings Cove Lighthouse facies. The Jones Pond facies (O'Brien and King, 2002) is now recognized as a localized channel lag, sub-facies within the Cape Bonavista facies.

Kings Cove Lighthouse Facies

The Kings Cove Lighthouse facies consists of grey, wavy-bedded, fine- to medium-grained, crossbedded sandstone interbeds with dark-purple, thin wavy laminations and mud drapes. The facies exhibits symmetric wave ripples (Plate 6A), imbricated intraformational rip-up clasts (Plate 6B, C) and trough crossbedding (Plate 6D). This unit outcrops sporadically throughout the western portion of the map area and is transitional both vertically and laterally with the Cape Bonavista facies and Kings Cove North facies (Figure 4). The Kings Cove Lighthouse facies has been moved down into the upper marine Rocky Harbour Forma-

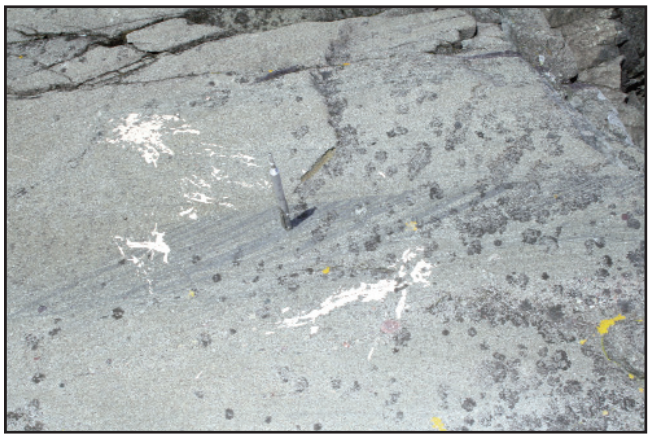

Plate 5. *Crosslamination of black detrital magnetite within a thick-bedded, poorly sorted sandstone typical of the Cape Bonavista facies; Devils Cove, Port Rexton. Note the distinctive bimodal sorted foresets in the crossbeds that also host well-rounded pebbles. Magnetic pointer is 13 cm long.*

tion as opposed to the terrestrial lower Crown Hill Formation of Normore (2010).

Trinity Facies

Description of the Trinity Facies

The Trinity facies of the upper Rocky Harbour Formation is a glaciomarine/glaciolacustrine laminated dropstone diamictite unit that has been extensively mapped in the Trinity map area. It outcrops from the town of New Bonaventure in the southwest of the Trinity map area to the north central map area where it is transected by the Northwest Pond resource road. It is green, (purple near faults), matrix-supported, poorly sorted, internally siltstone laminated dropstone diamictite, rich in well-rounded pebbles and cobbles. The facies varies in thickness from 15 m in the south to 100+ m in the north and shows a decrease in matrix grain size northward. The Trinity facies appears to be the result of

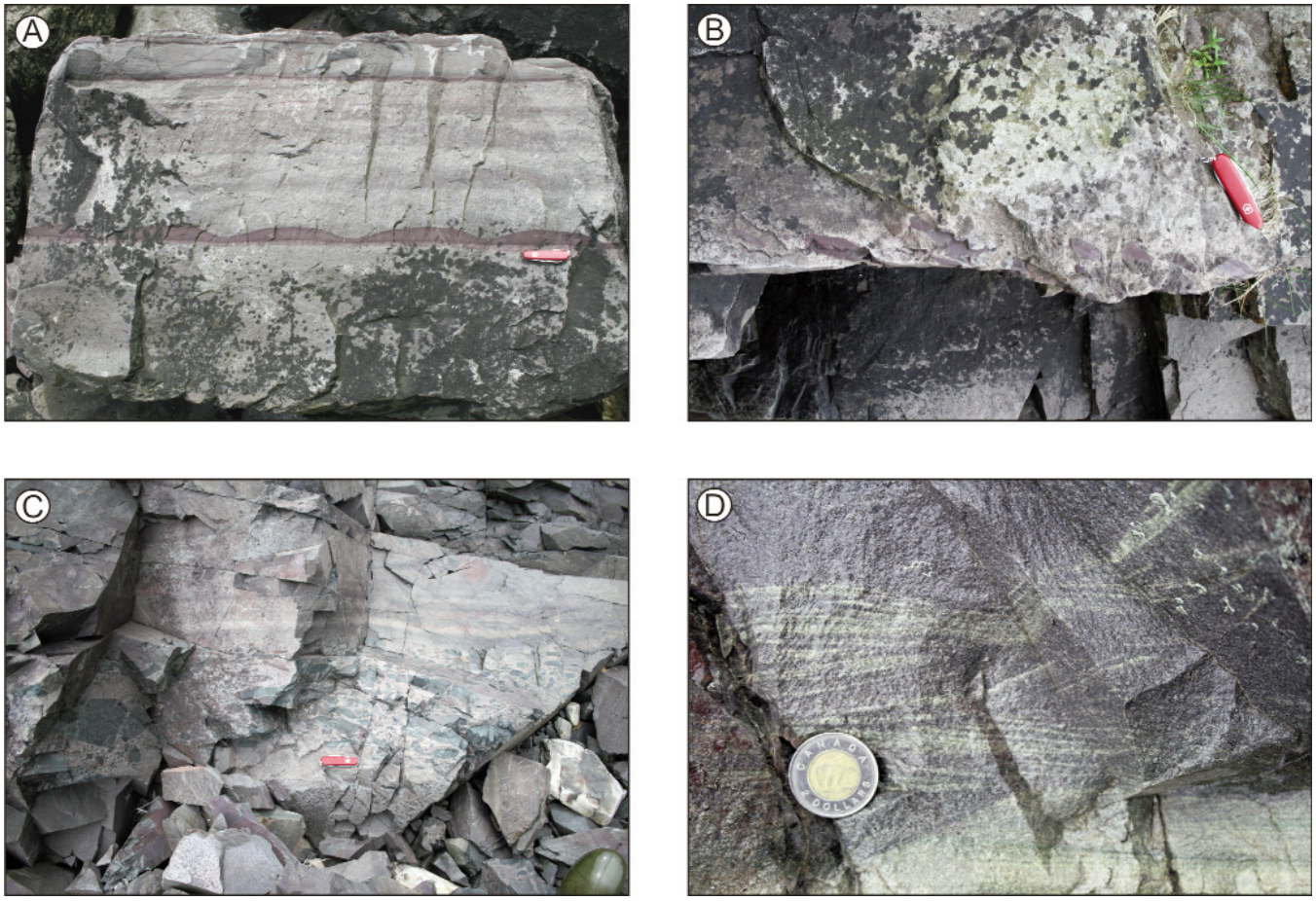

Plate 6. A) *Interbedded, low-angle crossbedded dark-grey, fine- to medium-grained sandstone and dark-purple siltstone displaying well-rounded symmetrical wave ripples, wavelength 35 cm, height 2 cm; south of Trouty Cove. Pocket knife is 9 cm long.* B) *Dark-purple, imbricated, sub-round, rip-up siltstone pebbles at the base of a sandstone bed within the Kings Cove Lighthouse facies, north of Trinity. Paleoflow to the left. Pocket knife is 9 cm long.* C) *Dark-grey, imbricated, angular, rip-up siltstone pebbles to platy cobbles within the Kings Cove Lighthouse facies, north of Trinity. Paleoflow to the left. Pocket knife is 9 cm long.* D) *Trough crossbedding within the Kings Cove Lighthouse facies, Trinity highway.*

rapid progradation providing variable lower and upper contacts with the Cape Bonavista, Kings Cove Lighthouse, Herring Cove and Kings Cove North facies (Figure 4). At one locality, south of New Bonaventure, the lower contact of the Trinity facies is with siltstones and volcanic rocks of the Herring Cove facies. The base of the Trinity facies at this outcrop consists of bi-directional crossbedded sandstone associated with large lensoid bodies of pebbly sediment, interpreted as shallow marine and iceberg-dump structures, respectively (Plate 7A), overlying intensely distorted and disrupted muddy laminated and thin-bedded fine-grained sediments (Plate 7B). The upper contacts of the Trinity facies are generally gradational into planar-laminated green siltstones of the Herring Cove and Kings Cove North facies (Figure 4). The Trinity facies is glacial in origin, with classic examples of dropstones (Plate 7C, D, E, G) and faceted clasts with glacial striations (Plate 7F). The variable thickness of the unit is likely a function of proximity to the ice-sheet margin, indicating an ice centre to the north.

Regional Correlation

The potential implications for stratigraphic correlations of Neoproterozoic glaciations across the Avalon Zone in Newfoundland (*see* Bruckner, 1977) and indeed worldwide, requires a review of glacial-deposited environments (Miller, 1996), glacial evidence; (Thomas and Connell, 1985) and Neoproterozoic glaciations (Harland *et al.,* 1966; Schermerhorn, 1974; Hambrey and Harland, 1981; Hambrey, 1994) in particular the Gaskiers glacial event (Bruckner and Anderson, 1971; Williams and King, 1979; Gravenor, 1980; Anderson and King, 1981; and Eyles and Eyles, 1989).

Whereas much dispute regarding specific ages of Neoproterozoic glacial periods exists, it is well documented that the Neoproterozoic glacial era ranks as the greatest glacial activity in Earth's history with glacial deposits identified on all continents, except Antarctica (Hambrey and Harland, 1981, 1985; Knoll and Walter, 1992) and linked to a snowball earth (Hoffman *et al.,* 1998). Worldwide Neoproterozoic glaciations have been moderately constrained with at least five glacial periods represented by the Sturtian 726–660 Ma, Marinoan 655–635 Ma (Hoffman and Li, 2009 and references therein), Gaskiers 582 Ma (Bowring *et al.,* 2003), Fauquier 571 Ma (Hebert *et al.,* 2010), Hongtiegou glaciation also postdating the Gaskiers glaciation (Shen *et al.,* 2010) and the Baykonur near the Precambrian–Cambrian boundary (Chumakov, 2009).

The Gaskiers glacial event is the best constrained (within 1.6 Ma) of all Neoproterozoic glaciations due to radiometric age dating of tuffs above and below the Gaskiers Formation at Great Colinet Island, St. Mary's Bay (Bowring *et al.*, 2003; *see* also Hoffman and Li, 2009). Several equivalent glacial deposits are recognized throughout the northern hemisphere (Halverson, 2006). The Squantum Tillite member of the Roxbury Conglomerate in the Boston Basin, eastern Massachusetts, has been correlated to the Gaskiers Formation and has been dated between 593 and 570 Ma (Thompson and Bowring, 2000; Thompson *et al.,* 2007). The glaciogenic Mortensnes Formation and the lower Moelv Tillite in Norway may also be coeval with the Gaskiers Formation (Bingen *et al.*, 2005; Nystuen, 2008), as well as the Hankalchough Formation in northwest China (Xiao *et al.,* 2004). Equivalents also exist in the southern hemisphere with the Cottons Breccia within the Rocky Cape Group of northwest Tasmania, which is the most closely constrained to the Gaskiers glaciation with radiometric dates of 582–575 Ma (Calver *et al.,* 2004).

The lack of radiometric dating in the Musgravetown Group provides little constraint on the age of the Trinity Rocky Harbour Formation for correlation with the Gaskiers glaciation. Stratigraphically below the Random Formation and above the Gibbet Hill Formation of the Signal Hill Group (King, 1988), the Rocky Harbour Formation can be assumed to be deposited above the Gaskiers Formation, somewhere between 565 Ma (Benus, 1988) and the Lower Cambrian (Anderson, 1981).

Herring Cove Facies

The newly defined Herring Cove facies comprises a mixed volcanic-sedimentary succession and signifies an abrupt change induced by volcanism. Volcanic rocks include rhyolite sills, waterlain tuffs and peperites. Sedimentary rocks include siliceous mudstone and wavy to parallel-laminated siltstone. Very thick-bedded peperites of varying intensities (Plate 8A to D), felsic dykes (Plate 9A), rhyolite sills (Plate 9B), and thin- to medium-bedded tuffs (Plate 9C, D) are found in the Herring Cove facies.

A distinctive peperitic bed approximately 2.5 m thick was mapped on the west side of Ass Hill (Ass Hill Conglomerate of Thorson, 2004; *see* Seymour *et al.,* 2004), in Sciff Cove, and on the south side of Southwest Trinity Arm. Volcanic glass shards found near the base of this peperite bed confirm a volcanic origin (Plate 8E). A peperite is formed when a volcanic flow mixes into wet unconsolidated sediments; it is commonly associated with syn-volcanic intrusions in submarine sedimentary sequences (White *et al.*, 2000; *see* Skilling *et al.* (2002) for an excellent review of peperites). Peperites are therefore an important facies, for several reasons. They are commonly associated with the early stages of Surtseyan eruptions (Kokelaar, 1983), they allow paleoenvironmental reconstructions, they may make potent geochronological tools and lastly, may be associated with hydrothermal alteration–mineralization, when circula-

Plate 7. *Caption on opposite page.*

Plate 7. (opposite page) A) *Bi-directional crossbedding and possible dump structure immediately below the diamictite-bearing Trinity facies, south of New Bonaventure. Lens cap is 5.8 cm diameter.* B) *Slumped horizon at the base of the Trinity facies, south of New Bonaventure.* C) *Boulder-sized dropstone clast within the Trinity facies at New Bonaventure. This example clearly shows the penetration of the dropstone through the underlying siltstone laminations (left side of clast) and the asymmetry between underlying and overlying strata, as distinct determination of glacial processes (Harland* et al.*, 1966).* D) *Purple matrix-supported well-rounded, poorly sorted diamictite of the Trinity facies showing a good example of a dropstone, located near Pudding Point, Northwest Trinity Arm.* E) *Photomicrograph of igneous dropstone penetrating thin sandstone lamination, within the Trinity facies at New Bonaventure; scale bar 1 mm increments.* F) *Two distinct striation orientations on a clast recovered from the Trinity facies from Northwest Pond resource road. Two additional sets of striations are found on the opposite side of the clast. G. Dropstones within the Trinity facies near New Bonaventure. Note the local zones of convoluted bedding, and the thin interbed of finely laminated pebble-free siltstone above lens cap.*

tion of basinal pore fluids is modified due to the transfer of heat from these intrusive bodies (Skilling *et al.,* 2002) and/or if magmatic fluids contribute to the basinal pore reservoir (Delaney, 1982). The presence of sediment-hosted stratiform copper in the immediate vicinity of Trinity may reflect this phenomenon.

Folded peperites are common in the Trinity area (Plate 8A, B, D; *cf.* Lorenz, 1984 and Brooks, 1995). They display pink subrounded, fluidal to globular felsic masses having dark-grey reaction rims in the lower part of the sedimentary bed to ropey and elongate, more stratiform felsic bodies near the top of the bed (Plate 8B). This indicates more intense mixing of lava in sediment, at the base of the bed, suggesting formation near the sediment–water contact. Coherent sills that intrude the sedimentary rocks at White Point and Trinity Highway near Trinity Pond, erode into the bounding siltstones of the Herring Cove facies. They may represent feeder conduits that supplied magma to peperite domains (*cf.* Hanson and Hargrove, 1999). Multiple tuff horizons overlying the peperites in the Herring Cove facies (Plates 9C, D) may also be sourced from the same magma body as the peperites beds.

Pink volcanic tuff, displaying tepee-like structures found in Herring Cove (Plate 9E) (sabka beds of Thorson, 2004; *in* Seymour *et al.*, 2004), occur interbedded with thinly laminated siltstones and thin- to medium-bedded tuffs. The tepee-like structures have a loaded basal contact with a thick devitrified tuff, and also have a linear trend. A welded tuff origin for the unit has been interpreted based on trace-element geochemistry (J. Hinchey, personal communication, 2010).

This facies intrudes and is interbedded with the Cape Bonavista and Kings Cove Lighthouse facies, is found above and below the Trinity facies and is generally overlain by the Kings Cove North facies (Figure 4).

Kings Cove North Facies

The sediments of the Kings Cove North facies in the Trinity map area consist dominantly of siliceous mudstone, wavy to parallel-laminated siltstone and lenticular fine-grained sandstone. The Kings Cove North facies is the uppermost facies of the Rocky Harbour Formation in the Trinity map area, interbedded with the Kings Cove Lighthouse and Trinity facies (Figure 4) but is overlain by the Kings Cove Lighthouse facies in the Bonavista map area near the contact with the terrestrial Crown Hill Formation (Normore, 2010).

NEOPROTEROZOIC ST. JOHN'S BASIN

The upper Conception Group fossiliferous sedimentary rocks found in the Bonavista map area (O'Brien and King, 2004; Hofmann *et al.,* 2008) are truncated by the Spillars Cove–English Harbour Fault in the Trinity map area. Gently folded sedimentary rocks of the St. John's and lower Signal Hill groups form anticline–syncline pairs on the northwest coast of Trinity Bay from English Harbour northeast to the northern boundary of the Trinity map area east of the Spillars Cove–English Harbour Fault.

St. John's Group

The St. John's Group is over 2500 m thick on the Bonavista Peninsula, outcropping from English Harbour in the Trinity map area to Elliston in the Bonavista map area (Normore, 2010). It gradationally overlies the Conception Group in the Bonavista map area (NTS 2C/11) but is in fault contact with the Rocky Harbour Formation in the Trinity map area (NTS 2C/06) across the Spillars Cove–English Harbour Fault. The St. John's Group is made up of the Trepassey, Fermeuse and Renews Head formations. In the English Harbour to Melrose area, turbiditic, medium-bedded, fine-grained sandstones and siltstones are found in the

Plate 8. A) *Peperite bed, approximately 2.5 m thick, located in Sciff Cove, south of Port Rexton. Tops is to the bottom right. Pocket knife is 9 cm long.* B) *Peperite bed, approximately 2.5 m thick located on the west side of Ass Hill, Robinhood Bay.* C) *Brecciated peperitic horizon, north of Green Island.* D) *Peperite bed, approximately 2.5 m thick, located on the west side of Ass Hill, Robinhood Bay.* E) *Photomicrograph of embayed glass shards from sample taken at the base of the peperite bed located on the west side of Ass Hill, Robinhood Bay. Scale bar 0.05 mm increments.*

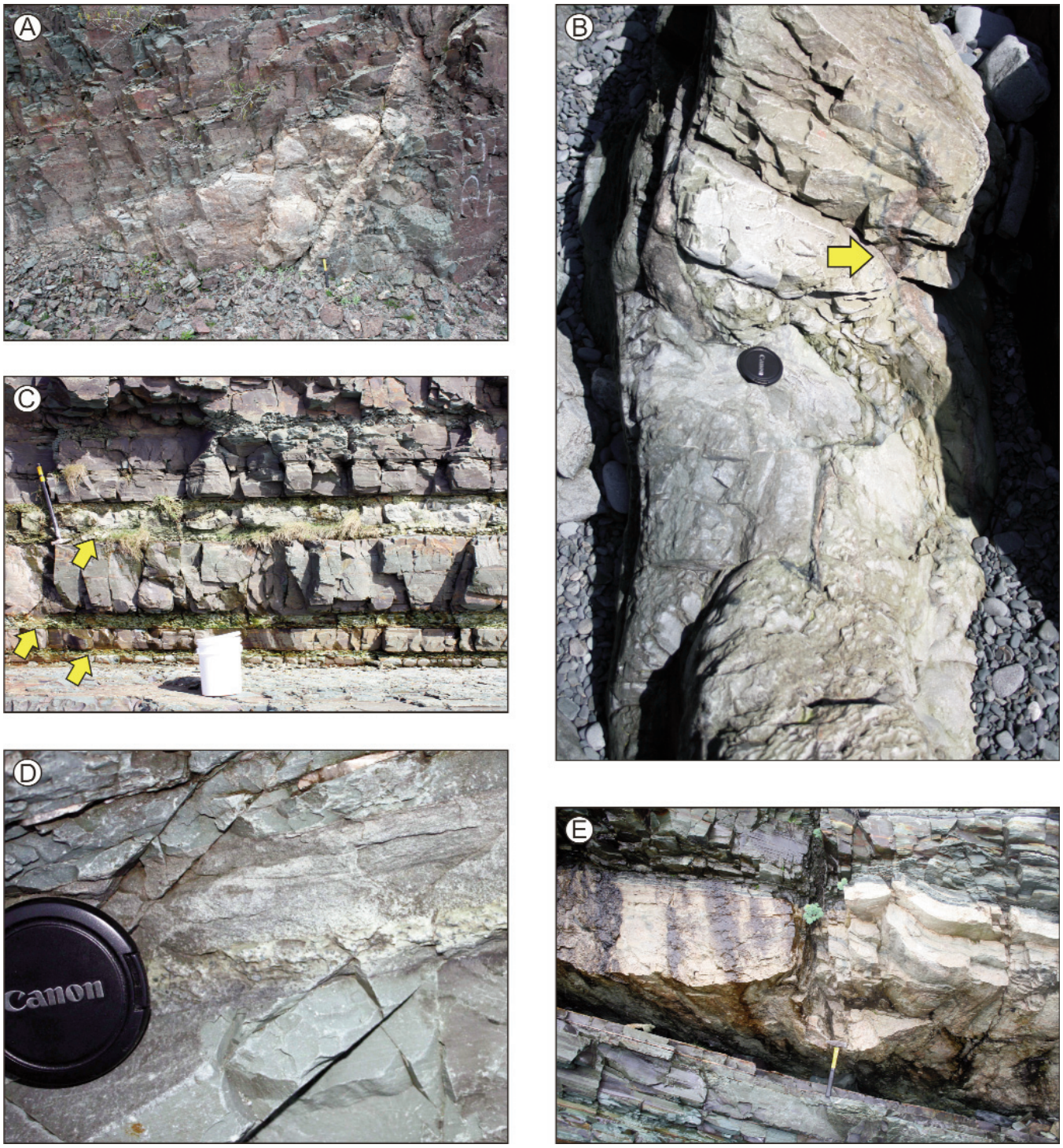

Plate 9. A) *A narrow felsic dyke intruding siltstones of the Herring Cove facies, Trinity highway (Route 230), south of Trinity Pond. Hammer is 37 cm long.* B) *Possible rhyolite sill within the Herring Cove facies, note elongate clast (yellow arrow) near upper boundary to the right; south of Sciff Cove, Trinity Bay. Lens cap is 5.8 cm diameter.* C) *Multiple tuff horizons increasing in thickness up section within the Herring Cove facies (yellow arrows at base of tuffs); Herring Cove, Trinity Bay. Hammer is 73.5 cm long.* D) *Pink tuff bed (by lens cap) sampled at Fox Island in the Fermeuse Formation for geochronological analysis. Lens cap is 5.8 cm diameter.* E) *A pink tuff bed showing a tepee-like structure, within the Herring Cove facies, Herring Cove, Trinity Bay. Hammer is 37 cm long.*

lowermost Fermeuse Formation, where they are transitionally overlain by black shale, siltstones and fine- to medium-grained sandstones of the upper Fermeuse Formation. The Renews Head Formation is in transitional contact with the Fermeuse Formation and consists of thin, lenticular-bedded sandstones and siltstones deposited during a shallowing-upward succession (King, 1990).

Trepassey Formation

The Port Union Member of the Trepassey Formation is the lowermost St. John's Group that outcrops in the Trinity map area, forming a small outcrop in the very north of the area at Back Cove. Abundant Ediacaran fossils have been documented in this area (O'Brien and King, 2004; Hofmann *et al.,* 2008).

Fermeuse Formation

The Fermeuse Formation outcrops from Back Cove to Oarblade Point, on the west coast of Trinity Bay, in the core of an anticline between English Head and Horse Chops, as a small sliver in English Harbour, and south of Champney's West (Figure 2). Siltstones are dark grey and thin bedded, whereas the sandstones are light grey and range from thin laminated to thick bedded. Large- and small-scale slumps (Plate 10A, B) are observed in the Fermeuse Formation in the Trinity map area as well as diagenetic redbeds (Plates 10C and 14A) and calcite cemented concretionary lens (Plate 10D).

The only Ediacaran body fossils found in the southern half of the Trinity map area were located in the Fermeuse Formation. The single outcrop that hosts abundant *Intrites punctatus* (Plate 10E) was discovered on the east side of Robinhood Bay south of Herring Cove. This Ediacaran body fossil is shaped like a doughnut 10 to 15 mm in diameter having a raised central pyritized core less than 3 mm diameter. McIlroy *et al.* (2005) document *Intrites punctatus* within the Burway Formation of the Stretton Group, Longmyndian Supergroup, Shropshire, UK that has been radiometrically dated between 555.9 ± 3.5 and 566 ± 2.9 Ma (Compston *et al.*, 2002). It is important to note, however, that the absence of well-defined species ranges for Ediacaran body fossils inhibits biostratigraphic correlation of Neoproterozoic strata (Knoll and Walter, 1992).

The Fermeuse Formation overlies the Trepassey Formation in the northeastern portion of the Trinity map area but is truncated by the Spillars Cove–English Harbour Fault at English Harbour, juxtaposed against the Kings Cove North facies.

Renews Head Formation

The Renews Head Formation contains distinctive sedimentary structures, such as lenticular bedding (Plate 11A), flame structures (Plate 11B), bi-directional climbing ripples (Plate 11C) and soft-sediment siltstone breccias (Plate 11D). It outcrops in northeast-trending synclinal structures between English Harbour and Melrose on the west coast of Trinity Bay (Figure 2). The Renews Head Formation gradationally overlies and coarsens upward from the underlying Fermeuse Formation.

Signal Hill Group

Grey, thick-bedded sandstones of the Signal Hill Group outcrop in a number of northeast-trending synclines along the coastline between English Harbour and Melrose (Figure 2) where they conformably overlie the Renews Head Formation. Excellent preservation of sharp-crested symmetrical wind ripples (Plate 12A) and well-rounded asymmetric ripples (Plate 12B, C) demonstrate a very shallow-marine depositional environment.

DYKES

Several mafic dykes cutting Musgravetown Group rocks were located during this summer's field work (*see* also Normore, 2010). The central portions of the dykes are generally dark-grey, dark-brown weathering, euhedral phanerit-

Plate 10. (opposite page) A) *Large slump fold in siltstone of the Fermeuse Formation, east side of Robinhood Bay.* B) *Recumbent slump folds, perhaps tightened by compaction within siltstones of the Fermeuse Formation, south of Herring Cove. The soft-sediment deformation may reflect rapid sediment accumulation or deposition on a slope. Pocket knife is 9 cm long.* C) *Discordant, fracture-related, zone of red oxidation within hackly fractured grey siltstone–mudstone of the Fermeuse Formation at English Harbour; the oxidation is potentially related to fluid flow along splays of the English Harbour–Spillars Cove Fault system.* D) *Calcite cemented concretion within the Fermeuse Formation on the east side of Robinhood Bay. Outer edge scale bar cm increments.* E) *Possible* Intrites punctatus *Ediacaran body fossils located in the Fermeuse Formation, south of Herring Cove, Robinhood Bay.*

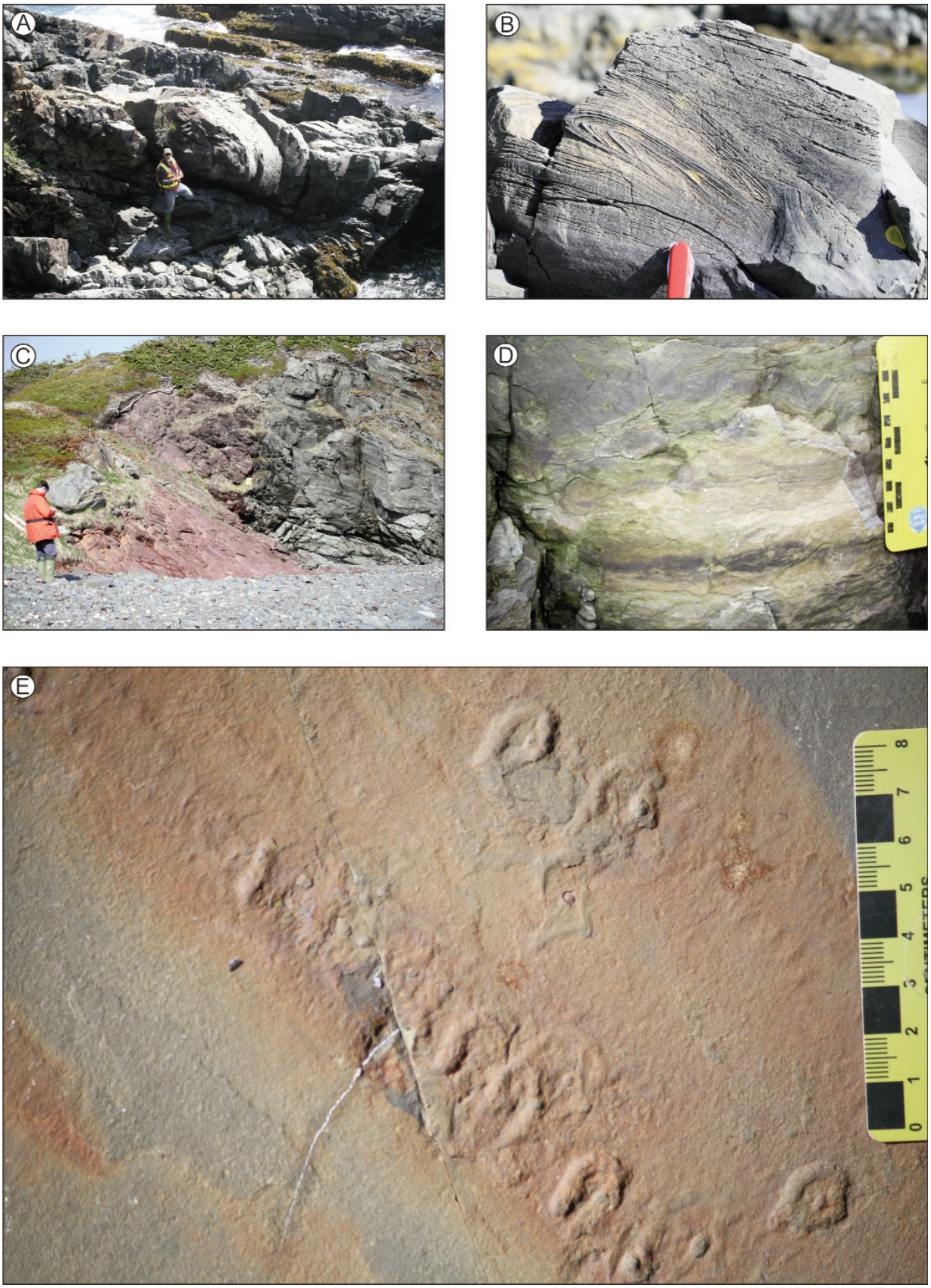

Plate 10. *Caption on opposite page.*

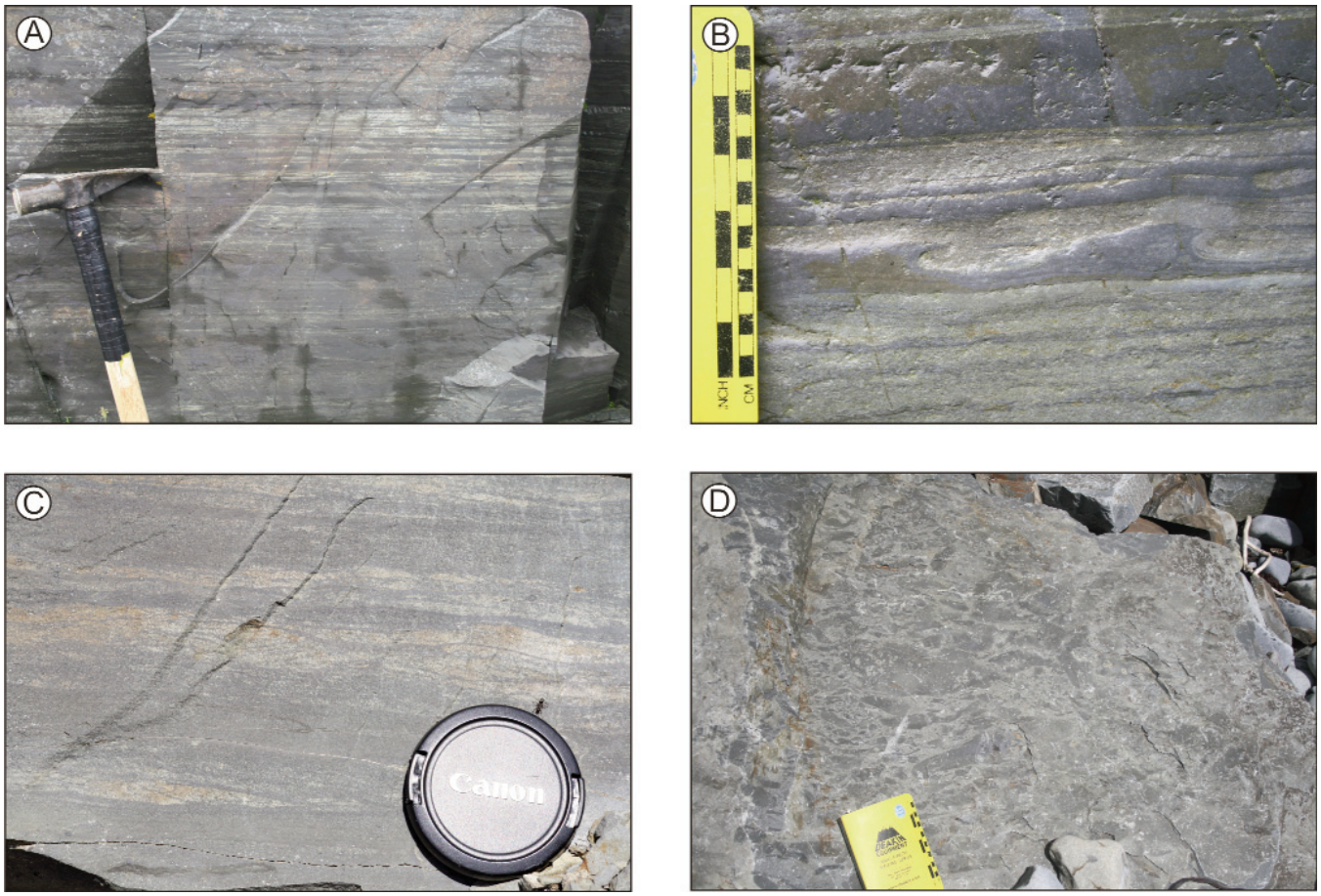

Plate 11. A) *Lenticular bedding, characteristic of the Renews Head Formation, Green Bay, western Trinity Bay. Hammer head is 19 cm long.* B) *Flame structures from the Renews Head Formation, Green Bay, western Trinity Bay.* C) *Lenticular bedding and bi-directional climbing ripples within the Renews Head Formation, between English Harbour and Horsechops. Lens cap is 5.8 cm across.* D) *Dark-grey, intraformational siltstone breccia within the upper Renews Head Formation on the north side of Northern Cove, northwest Trinity Bay.*

ic diabase bordered by aphanitic margins replete with quartz veining at the contacts with the sedimentary rocks. The largest dyke in the area was located on the highway between Port Union and Port Rexton (Plate 13) and was traced to Salmon Cove Brook north of Route 230 and near to the cell tower on Lockston Path. This 4.5-m-thick dyke is offset dextrally up to 1 km by the Robinhood Bay Fault, suggesting emplacement of the dykes following folding but prior to fault deformation. Other dykes occur near Freshwater Bay and Walter Point in Northwest Trinity Arm.

STRUCTURE

Several major northeast and northerly trending fault zones are recognized in the Bonavista Peninsula. The Duntara Fault and Stock Cove Lineament within the Bonavista map area (Figure 2, Normore, 2010) and the Trinity Pond and Trouty Pond faults within the Trinity map area are northeast-trending structures that parallel the Dover Fault, the western boundary of the Avalon Zone in northeast Newfoundland. North-trending structures such as the Spillars Cove–English Harbour Fault and the Robinhood Bay Fault are arcuate, suggesting folding by an earlier phase of deformation. The southern end of the Spillars Cove–English Harbour Fault extends west through Champney's West and is truncated by the Robinhood Bay Fault, which is in turn truncated by the Trinity Pond Fault in the central part of the Trinity map area providing relative timing of faulting (Figure 2).

Discordant reduction-oxidation contacts (Plate 14A) and calcite cemented concretionary lens are well developed in several places throughout Champneys West, Fox Island and English Harbour. The redox boundaries appear to be related to faulting (Plate 10C), and fluid flow through splays of the Spillars Cove–English Harbour Fault. Abundant localized pyrite and a rare occurrence of jasper is also associated with these faults in Fox Bay.

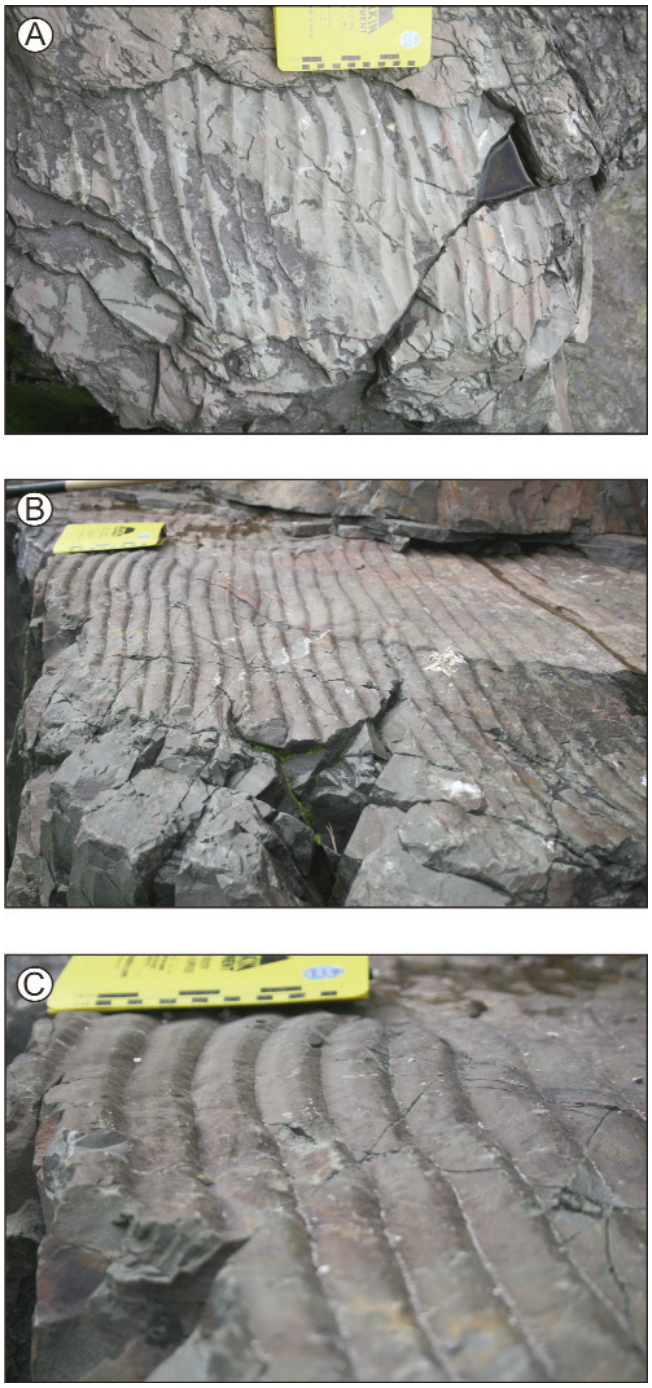

Plate 12. *A) Sharp-crested symmetrical ripples in the Gibbet Hill Formation, near Norther' Point, western Trinity Bay.* B) *Rounded, asymmetric ripples in the Gibbet Hill Formation, near Norther' Point, western Trinity Bay. Paleoflow to the right is bearing northwest.* C) *Close-up of rounded, asymmetric ripples in Plate 12B.*

Large, open south-plunging anticline-syncline pairs in the west-central portion of the map area are associated with a series of northeast-directed imbricate thrust sheets (Plate 14B) that repeat the stratigraphic successions throughout the south-central portion of the map area. East of the Spillars Cove–English Harbour Fault, sedimentary rocks of the St. John's Basin are gently folded, characteristic of the St. John's Basin as a whole.

Plate 13. *A 4.5-m-wide mafic dyke sharply cutting bedded siltstones and lenticular fine-grained sandstones of the Big Head Formation on Route 230 between Port Rexton and Port Union.*

CONCLUSIONS/FUTURE WORK

The division of the Bonavista Peninsula into two distinct, juxtaposed Neoproterozoic sedimentary basins (O'Brien and King, 2002; Normore, 2010) is confirmed based on field work on the Trinity map area (NTS 2C/06) during the 2010 season. The absence of the fossiliferous Trepassey and Mistaken Point formations in the southern half of the Trinity map area, in contrast to their thick succession in the Bonavista map area, the rapid change to shallow-marine depositional environments to the west of the Spillers Cove-English Harbour Fault and the distinctive change in aeromagnetic signature across this boundary, supports a faulted relationship.

The presence of a widespread glaciomarine Trinity facies provides another possibly younger Neoproterozoic glacial event in the Avalon Zone. Several lines of evidence refute any correlation with the Gaskiers Formation. The facies association of the Trinity facies within the Rocky Harbour Formation indicates a shallow-marine setting for the Trinity facies in the Bonavista Peninsula area rather than the deep-marine slope environment of the Gaskiers Formation (Eyles and Eyles, 1989). Previous mapping places the Rocky Harbour Formation above the Signal Hill Group and below the Random Formation, in a younger stratigraphic position than the lower Conception Group (King, 1988). Also, the thick nature of the Trinity facies diamictite does not correspond to the remobilized glacial diamictites,

Plate 14. A) *Oxidation front along a fault within the Fermeuse Formation near Fox Island.. B*) *A north-directed thrust fault (arrow defines the thrust plane) near Herring Point displacing sediments within the Monk Bay facies.*

interbedded with sandstone, conglomerate and volcaniclastic characteristic of the Gaskiers Formation.

Local aeromagnetic surveys would be beneficial for highlighting additional volcanic and intrusive rocks in the area. A regionally unified stratigraphic framework may also assist with exploration of large tonnage sediment-hosted stratiform copper deposits in this region. Ongoing work on the radiometric dating of tuffs above, and below, the Trinity facies will help determine the stratigraphic relationship between the Trinity facies and Gaskiers Formation in the Avalon Zone, as a correlative or a younger Ediacaran glaciation in the Avalon Zone.

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