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REFINING THE TECTONOSTRATIGRAPHY OF THE BAIE VERTE PENINSULA: NEW INSIGHTS FROM FIELD AND GEOCHRONOLOGICAL DATA

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ABSTRACT

The Baie Verte Margin in western Newfoundland exposes Laurentian basement and cover sequences, but the architecture of these units has remained controversial. Here, we integrate new field observations with U–Pb zircon geochronology to clarify long-standing ambiguities in the tectonostratigraphic definition of the East Pond Metamorphic Suite (EPMS). The lowest structural levels contain a heterogeneous assemblage of syenogranite and metamonzogranite, paragneiss–orthogneiss, banded grey gneiss, felsic tuff, pelitic layers, and eclogite–amphibolite. Preliminary results suggest that a pegmatite sample yields discordant U–Pb zircon dates with an upper intercept at ca. *1.49 Ga, overprinted by Grenvillian (*ca. *1.01 Ga), Tonian (*ca. *0.94 Ga) and Ediacaran (*ca. *552 Ma) metamorphism. In contrast, detrital zircon spectra from the EPMS show prominent Tonian–Mesoproterozoic age populations and yield Ediacaran maximum depositional ages (*ca. *565 Ma), indicating greater internal complexity than previously recognized and the presence of a Neoproterozoic volcano-sedimentary cover distinct from the underlying reworked basement. Together, these data demonstrate a long-lived pre-EPMS history recorded by the basement rocks. We formalize this basement section as the Middle Arm Brook Complex (MABC) and the albitized high-strain boundary between the EPMS and Old House Cove Group (OHCG) as the Bear Cove Road Shear Zone (BCRSZ). This revised framework strengthens regional correlations of the Baie Verte Margin within the broader Laurentian margin and supports links to mineralized equivalent Dalradian–Grampian successions in Ireland and Scotland.*

INTRODUCTION

The Baie Verte Margin of the Newfoundland Appalachians is exposed east of Cabot Fault and west of the Baie Verte–Brompton Line (BVBL) and is characterized by Proterozoic basement rocks of the East Pond Metamorphic Suite (EPMS) and unconformably overlying metasedimentary and meta-igneous rocks of the late Neoproterozoic to early Paleozoic Fleur de Lys Supergroup (FdLS; Hibbard, 1983; van Staal *et al.*, 2013). The Baie Verte Margin provides an example of a reworked continental-margin setting, preserving Laurentian basement and cover units recording intricate records of sedimentation, magmatism, metamorphism and deformation (*e.g.*, van Staal *et al.*, 2012). In this context, the Baie Verte Margin located on the western Baie Verte Peninsula, offers a key window into the early Paleozoic evolution of the Laurentian margin. The tectonostratigraphy of the peninsula, however, remains uncertain, particularly regarding the basement–cover and age relationships within the EPMS and the FdLS. Decades after the original mapping (*e.g.*, de Wit, 1980; Hibbard, 1983), the age and the existence of a distinct basement to the FdLS sedimentary rocks remain debated, with the EPMS variably interpreted as Laurentian basement, as the infrastructure of both basement and cover, or as part of a relatively conformable FdLS sequence (de Wit and Strong, 1975, 1980; Hibbard, 1983; Piasecki, 1987, 1988; de Wit and Armstrong, 2014). In addition, intense Paleozoic tectonic overprints obscured the original characteristics and relationships of the basement and its cover (de Wit, 1980; Jamieson, 1990; de Wit and Armstrong, 2014).

Refining the basement–cover architecture of the Baie Verte Margin strengthens correlations with the Grampian terrane of Ireland and Scotland, where equivalent units host significant orogenic gold systems (*e.g.*, Rice *et al.*, 2016; Zagorevski *et al.*, 2024). Hence, resolving the structural architecture and history of the Baie Verte Margin improves our ability to identify which Newfoundland successions may correlate to mineralized Dalradian belts, highlighting the exploration relevance of this research into bettering our understanding of the tectonostratigraphy. This contribution integrates new field observations and U–Pb geochronological data to refine the architecture of the Baie Verte Margin and to provide insights into the evolution of the Laurentian margin reworked during the Taconic and subsequent orogenic cycles.

GEOLOGICAL BACKGROUND

The currently recognized tectonostratigraphic architecture of the Baie Verte Margin (Figure 1) consists of a Mesoproterozoic basement represented by the EPMS, its Neoproterozoic to Early Ordovician cover of the FdLS, and the outboard ophiolitic and volcanic sequences of the Baie Verte Oceanic Tract (BVOT) and associated arc complexes situated east of the BVBL (Figure 1; de Wit, 1980; Hibbard, 1983; van Staal *et al.*, 2007; de Wit and Armstrong, 2014; Skulski *et al.*, 2015). This architecture, however, presently reflects a working model rather than a universally accepted framework, as the definition and extent of the FdLS "basement" and its distinction from the overlying FdLS have been the subject of long-standing debate (de Wit, 1980; Hibbard, 1983; Piasecki, 1987, 1988; de Wit and Armstrong, 2014). The continental Baie Verte Margin is interpreted as a hyper-extended segment of the Laurentian margin that underwent protracted rifting during the opening of the Taconic (Iapetus) seaway and was subsequently subducted, metamorphosed and exhumed during the Early to Middle Ordovician Taconic orogenic cycle (van Staal *et al.*, 2007, 2013; Castonguay *et al.*, 2014; Scorsolini *et al.*, 2025a, b).

The EPMS forms the metamorphic basement to the FdLS and is composed of migmatitic paragneiss, granitic orthogneiss, psammitic to semipelitic gneiss, amphibolite and minor quartzite (de Wit, 1980; de Wit and Armstrong, 2014). Zircon U–Pb geochronology of a granitic gneiss from the EPMS records a Pinwarian crystallization date of 1491 ± 19 Ma (2σ) for the magmatic protolith, subsequently overprinted by Grenvillian metamorphism at 966 ± 33 Ma (2σ; de Wit and Armstrong, 2014). The Pinwarian basement is structurally overlain by the Tonian Pine Pond succession, a bimodal volcanic and sedimentary sequence dated between 979 ± 14 and 952 ± 10 Ma (2σ), interpreted as an extensional cover unit related to Neoproterozoic rifting (Strowbridge *et al.*, 2022). During the Taconic orogeny, the EPMS was subducted beneath the Notre Dame arc (van Staal *et al.*, 2007) and metamorphosed to eclogite-facies conditions at pressures up to 2.7 GPa and temperatures near 640°C (Scorsolini *et al.*, 2025a). Eclogite-facies metamorphism at 483 ± 18 Ma (2σ; U–Pb rutile) was followed by amphibolite-facies overprinting and partial re-equilibration during progressive deformation associated with cooling and exhumation between 461 ± 7 Ma (2σ; Rb–Sr phengite) and 452 ± 16 Ma (2σ; U–Pb apatite) (Scorsolini *et al.*, 2025b). The EPMS metamorphic evolution defines a multistage exhumation path characterized by near-isothermal decompression and late heating during ascent, producing a β-shaped P–T–t trajectory (Scorsolini *et al.*, 2025a). Late Taconic pegmatites that crosscut the eclogites yield magmatic zircon dates of 451 ± 3 Ma (2σ), recording magmatism during the final stages of uplift and cooling (Scorsolini *et al.*, 2025b).

The FdLS is structurally emplaced above the EPMS along a high-strain shear zone, originally described as "tectonic schist" by de Wit (1980) and later formalized as a separate map unit by Skulski *et al.* (2017). The FdLS protoliths are generally considered to have been derived from sedimentary sequences deposited along the rifted Laurentian margin (Bursnall and de Wit, 1975; Williams, 1977; Hibbard, 1983; Cawood et al., 2001; White and Waldron, 2022). Maximum depositional ages of correlative units to the FdLS in southwestern Newfoundland of 580–570 Ma (Cawood and Nemchin, 2001) are similar to sedimentation ages in the Dashwoods terrane (563–500 Ma; Zagorevski *et al.*, 2024), the basement to the Notre Dame arc, and overlap with depositional ages of the Dalradian Supergroup of western Ireland (Riggs *et al.*, 2022) and the Tyrone Central Inlier (Chew *et al.*, 2008). The FdLS includes three tectonostratigraphic units (Figure 1). The Birchy Complex, representing the ocean–continent transition, comprises psammitic and pelitic schists interbedded with tholeiitic metabasalt, metagabbro, and mélange containing ultramafic blocks. Mafic intrusions yield U–Pb zircon dates of 564–558 Ma, marking late Ediacaran rifting (van Staal *et al.*, 2013; Skulski *et al.*, 2015). The Rattling Brook Group, interpreted as an extensional allochthon originally conformable on the Birchy Complex, consists of mafic schist, marble, and calcareous pelite. Both complexes were metamorphosed under amphibolite-facies conditions during the Ordovician, with $^{40}Ar/^{39}Ar$ hornblende and mica dates between 467 and 453 Ma recording retrogression accompanying D_2 and D_3 deformation (Castonguay *et al.*, 2014; Willner *et al.*, 2022). The more inboard units represent para-autochthonous Laurentian-margin successions of psammitic to semipelitic schists, marbles, and quartz-pebble conglomerates that were metamorphosed to greenschist–amphibolite facies and locally migmatized during Silurian magmatism associated with the Wild Cove Pond Suite (428–423 Ma; Cawood and Dunning, 1993; Castonguay *et al.*, 2010; Skulski *et al.*, 2017).

The deformation history of the Baie Verte Margin comprises at least five events. D_1–D_2 correspond to subduction- and early exhumation-related deformation between *ca.* 485 and 460 Ma (Castonguay *et al.*, 2014; Scorsolini *et al.*, 2025a, b). D_3, dated between *ca.* 428 and 423 Ma, generated

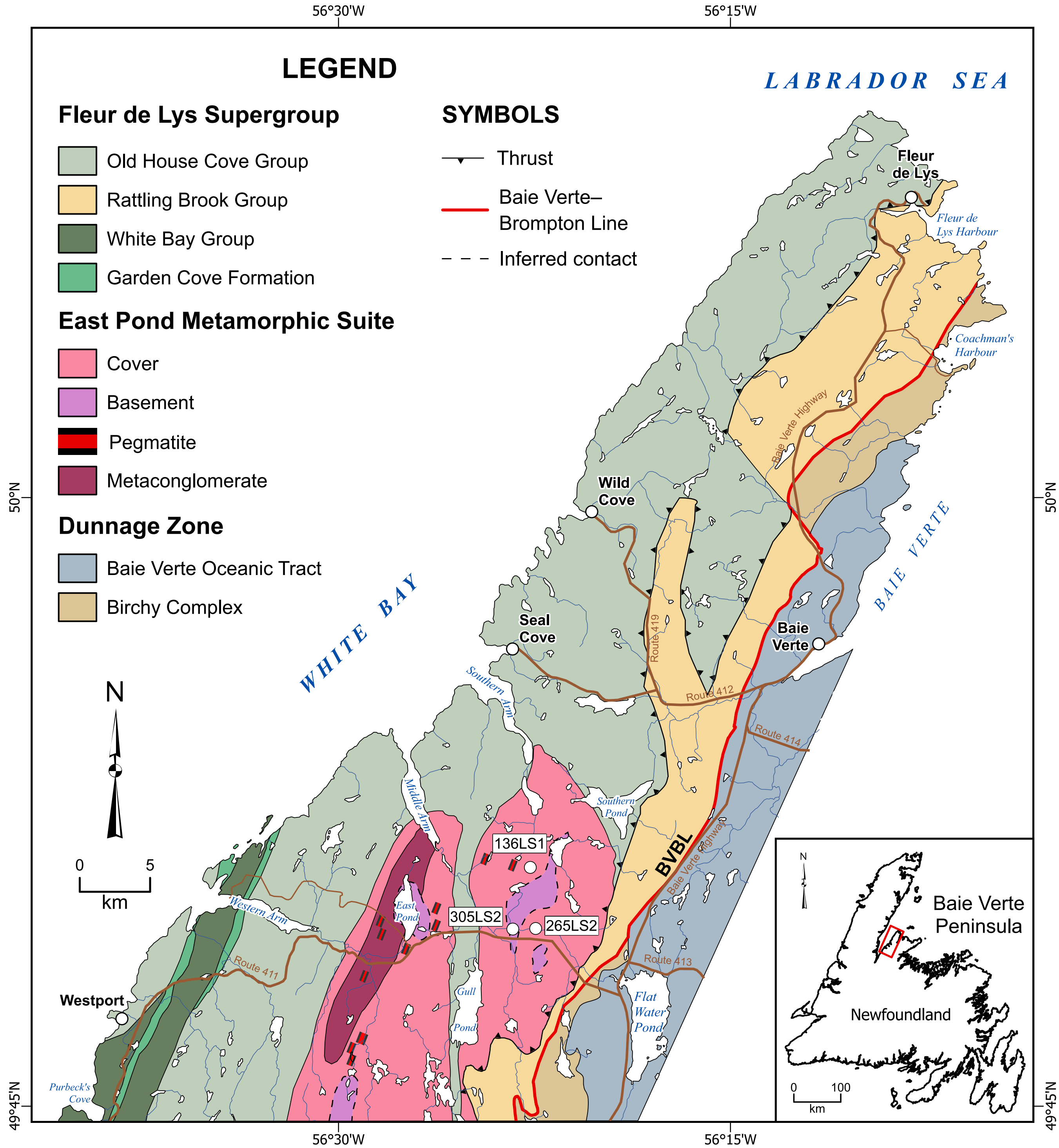

Figure 1. *Bottom-right inset: Location of the Baie Verte Peninsula within Newfoundland. Main diagram: Summary geological map of the Baie Verte Margin. The distribution of map units and major tectonic lineaments is integrated with geological maps compiled by the Geological Survey of Canada (Skulski* et al.*, 2017). BVBL–Baie Verte–Brompton Line.*

the dominant northeast-trending foliation and amphibolite- to greenschist-facies recrystallization contemporaneous with the Wild Cove Suite intrusions (Cawood and Dunning, 1993; Dallmeyer, 1977; Castonguay *et al.*, 2010, 2014; Skulski *et al.*, 2017; Willner *et al.*, 2022). D_4–D_5 deformation in the Devonian (405–356 Ma) reflects later transpressional deformation and subsequent extensional reactivation along the BVBL, accompanied by local amphibolite-facies shear-zone development (Neale *et al.*, 1967; Hibbard, 1983; Goodwin and Williams, 1996; Anderson *et al.*, 2001). Together, these units preserve an intricate geologic record spanning Mesoproterozoic Laurentian basement formation, Neoproterozoic metamorphic overprinting, Tonian volcanism, Ediacaran rifting and hyperextension, Ordovician subduction and exhumation, and Siluro–Devonian reworking.

ANALYTICAL METHODS

Three samples were selected representing important magmatic (sample 305LS2), sedimentary (sample 265LS2), and volcanoclastic events (sample 136LS1) and their ages will help refine the tectonostratigraphy of the Baie Verte Margin (Figure 1; *see* included supplementary data). Zircon separation was done at University of Waterloo (UW) using a combination of crushing, sieving, panning and heavy liquid techniques, and at Overburden Drilling Management (ODM) Limited, Canada, using a combination of electronic pulse disaggregation (EPD), shaking table concentration and micropanning. Grains were mounted in epoxy resin and polished to reveal the crystal interiors. Cathodoluminescence (CL) imaging of zircon was done using a JEOL JSM 7100F Field Emission Gun Scanning Electron Microscope (FEG-SEM) at The Earth Resources and Analysis (TERRA) Facility at Memorial University of Newfoundland (MUN) to characterize the internal structure(s), morphology, and mineral inclusions. Minerals were identified using energy-dispersive spectroscopy (EDS) at 15 kV and 50 nA. The epoxy mounts were used for subsequent investigations using Laser Ablation-Inductively Coupled Plasma Mass Spectrometry (LA-ICPMS).

U–Pb AND TRACE-ELEMENT ANALYSIS

Uranium–Pb isotopes and trace-element analyses were simultaneously done at the Micro Analysis Facility (MAF) at MUN using a Thermo-Finnigan Element XR ICP-MS in combination with a Geolas 193 nm ArF Excimer laser. Helium gas with a flow rate of 1.25 L/min was used to transport the ablated material, with N_2 added to the Ar carrier gas for increased sensitivity, and additional Ar make-up gas added after the ablation cell before injection into the ICP-MS. After collecting a background for 30 seconds, the samples were ablated for 60 seconds. Zircon grains were analyzed using a laser spot size of 30 µm at a repetition rate of 5 Hz and a laser fluence of 4.0 J/cm^2. Zircon material 91500 (1062 Ma, Wiedenbeck *et al.*, 1995) and Plešovice (337 ± 1 Ma, Slama *et al.*, 2008) were used as primary reference materials, and 02123 (295 ± 1 Ma, Ketchum *et al.*, 2001) was used as a secondary reference material.

For every grain analyzed for U–Pb geochronology, the primary reference material for trace-element analysis was NIST 610 with NIST 612 and USGS BCR-2G used as the secondary reference material. Iolite software v.3 (Paton *et al.*, 2011) was used for all U–Pb and trace-element data reduction. For U–Pb geochronology, an exponential-linear downhole U–Pb fractionation correction model was used. Isoplot 3.7 (Ludwig, 2003) was used for age calculations, and the age uncertainties are reported at the 2σ (95%) confidence level.

RESULTS

FIELD RELATIONSHIPS

The lower structural unit occurs within regional F_3 antiformal fold cores (Figure 1). Its dominant lithologic associations include metasyenogranite (Plate 1A), metamonzogranite (Plate 1B), metagranodiorite (Plate 1C), grey gneiss (Plate 1D), orthogneiss (Plate 1E), mafic boudins (Plate 1F), pegmatite dykes (Plate 2A), felsic tuff (Plate 2B) and psammite–pelite sequences (Plate 3C). Metasyenogranite, locally grading to metagranite, mainly consists of quartz–plagioclase–microcline–biotite and is locally preserved as massive bodies containing biotite-rich enclaves (Plate 1A), consistent with the granitic to syenogranitic gneisses described in the pre–Fleur de Lys basement by de Wit (1980) and Hibbard (1983). Metamonzogranite (Plate 1B) consists of resorbed biotite porphyroblast and polycrystalline aggregates of K-feldspar–plagioclase–quartz–biotite ± amphibole. Metamonzogranite is currently documented at one locality, and its relationships with adjacent units are unclear. Metagranodiorite, locally grading into metatonalite, is strongly recrystallized and displays a fabric of polycrystalline quartz–plagioclase–biotite–epidote ± K-feldspar ± amphibole aggregates set within a biotite-rich matrix (Plate 1C). Orthogneiss (Plate 1E) is interpreted as the product of deformation and amalgamation of these metaplutonic lithologies (*e.g.*, syenogranite gneiss, metagranodiorite, metatonalite), locally incorporating metasedimentary components. This rock type is consistent with the "mixed layered gneiss" described by de Wit (1980) in the pre–Fleur de Lys basement. Grey gneiss (Plate 1D) consists of quartz–plagioclase–biotite ± hornblende showing decimetre- to metre-scale compositional layering and tight to isoclinal intrafolial F_1 folds. These features are consistent with the grey gneiss described by de Wit (1980), who reported gradational transitions into granitic–granodioritic gneiss. Mafic

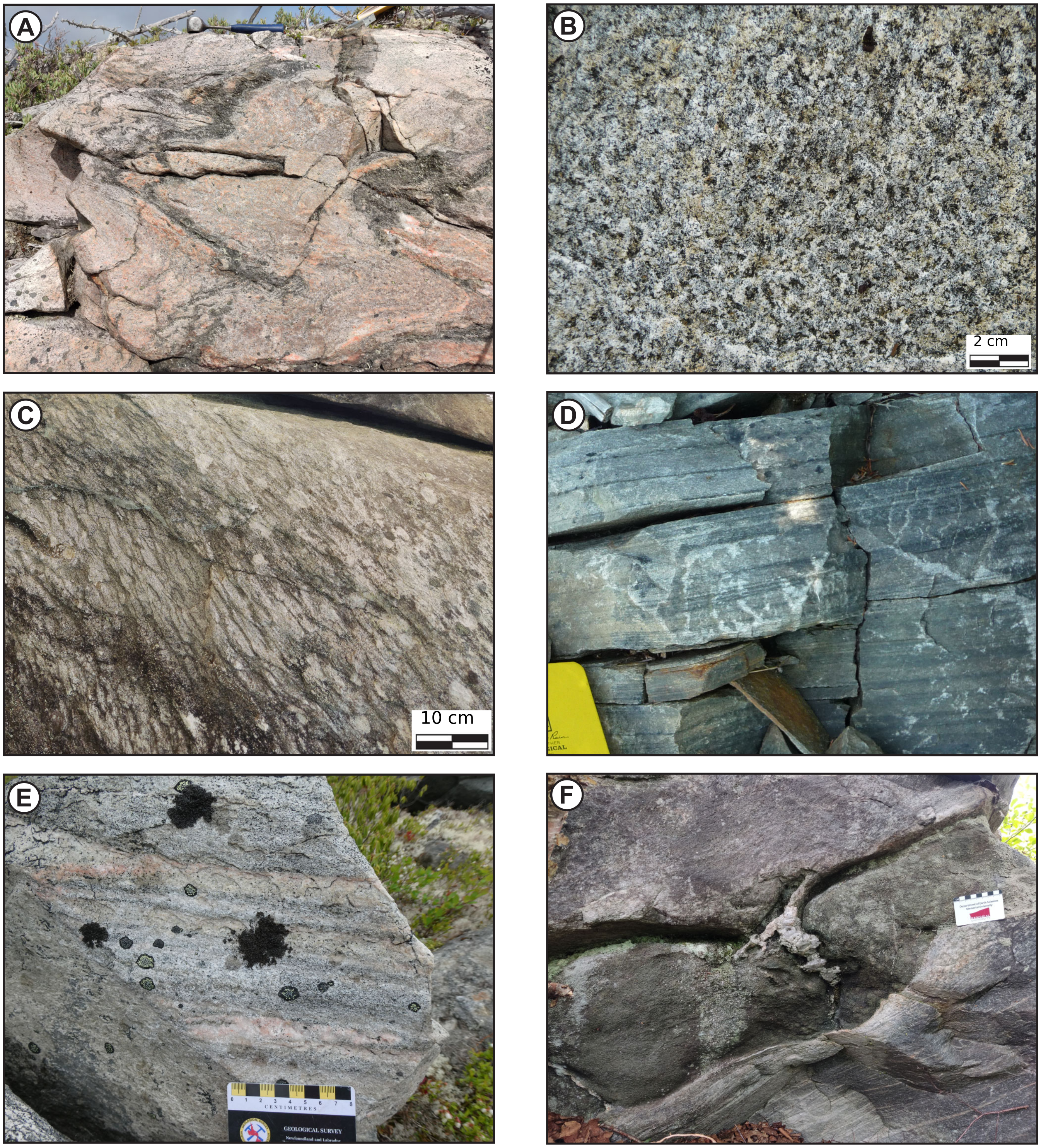

Plate 1. *Field photographs of characteristic lithologies defining the lowest structural unit of the Baie Verte Margin. A) Metasyenogranite, composed of quartz–plagioclase–microcline–biotite, preserved as massive pink bodies and dykes locally containing biotite-rich enclaves; B) Metamonzogranite, consisting of resorbed biotite porphyroblasts and polycrystalline K-feldspar–plagioclase–quartz–biotite ± amphibole aggregates; C) Metagranodiorite, strongly recrystallized and characterized by polycrystalline quartz–plagioclase–biotite–epidote ± K-feldspar ± amphibole aggregates in a biotite-rich matrix; D) Grey gneiss consisting of quartz–plagioclase–biotite ± hornblende with compositional layering highlighted by different biotite modal abundances; E) Orthogneiss with gneissic layering marked by bands of syenogranite and metagranodiorite; F) Mafic boudin preserving amphibolite-facies assemblages, with pegmatite intruding the boudin neck.*

boudins contain biotite–plagioclase–epidote–chlorite–titanite assemblages, locally accompanied by rutile, amphibole, and garnet (Plate 1F). They range from centimetre to tens of metres in size, cut metagranodiorite and orthogneiss, are boudinaged and strongly transposed by pre-D_3 deformation. Most boudins preserve amphibolite- to epidote–amphibolite-facies assemblages, although garnet–omphacite–quartz–rutile ± amphibole eclogite facies assemblages are locally preserved. Pegmatite dykes (Plate 2A) intrude syenitic gneiss, orthogneiss, and locally occupy mafic boudin necks, indicating emplacement during deformation. Both crosscutting and layer-parallel dykes occur, and all are tightly folded by recumbent isoclinal folds predating regional F_3 folding. Felsic tuffs form laminated beds a few decimetres to ~2 m thick (Plate 2B) and contain plagioclase phenocrysts up to 3 mm. They occur conformably interlayered with white-mica–rich psammites (Plate 2C) and biotite- and tourmaline-bearing pelites up to a metre thick.

Psammitic to semipelitic sequences with minor pelitic and volcanoclastic interbeds, and a basal conglomerate unit are characteristic of the EPMS. The Middle Arm Metaconglomerate is a polymictic conglomerate exposed in proximity to a F_3 antiformal fold core, and it marks the base of the psammite sequence (Plate 2D). The pebbly fraction of the conglomerate progressively decreases towards higher structural levels, where it grades into the psammite sequence. EPMS psammites (Plate 2E) consist of quartz–plagioclase–white mica–biotite–epidote–apatite–garnet ± K-feldspar ± rutile ± titanite assemblages and are consistently bedded and interlayered with thin semipelite–pelite beds, generally only a few centimetres thick but locally reaching up to ~25 cm. The psammites exhibit brown to yellowish weathering; they are heterogeneously deformed, with the highest strain commonly recorded along the limbs of F_2 and F_3 folds. Gossanous psammite or psammite with disseminated sulphides (Plate 2F) occurs proximal in correlation with northeast–southwest-directed, locally albitized shear zones. In low-strain areas, mainly located in F_3 hinge zones, EPMS metasediments locally preserve pristine primary structures, including partial Bouma sequences, flame structures, load structures and rip-up clasts (Plate 2E). The EPMS metasediments commonly contain layering-parallel mafic boudins metamorphosed to eclogite and amphibolite (Scorsolini *et al.*, 2025a, b), and less commonly quartzite and volcanic layers (Plate 3A). Late, undeformed to weakly foliated pegmatite intrusions are common in some localities (*cf.*, Scorsolini *et al.*, 2025b), where they crosscut the layering and the internal, amphibolite-facies foliation of the mafic boudins (Plate 3B).

The EPMS is structurally overlain by the Old House Cove Group (OHCG) across a kilometre-scale shear zone whose thickness varies from several tens of metres to nearly 1 km. This zone consists of schistose, strongly albitized rocks, derived from the deformation of psammites and mafic boudins belonging to both juxtaposed units. The OHCG comprises bedded psammite and pelite (Plate 3C), locally preserving graded bedding, along with abundant albite-rich amphibolite boudins (Plate 3D) and minor pegmatite and granite dykes and sheets. The OHCG psammites and semipelites locally contain garnet–albite ± staurolite ± kyanite porphyroblasts. Compared to the EPMS psammites, those of the OHCG are generally coarser grained and richer in biotite and feldspars, but their most diagnostic feature is the pervasive albitization that affects all lithologies and locally accounts for up to ~60% of the total modal composition.

SAMPLE DESCRIPTIONS

Sample 136LS1 is a foliated metasandstone composed of quartz–plagioclase–white-mica–biotite–garnet–epidote–rutile. The rock is fine to medium grained, with an average grain size of 0.5–1 mm and contains subidioblastic garnet porphyroblasts up to ~2 mm in diameter hosting inclusions of rutile and quartz. The dominant foliation (S_2) is defined by the shape-preferred orientation of quartz, plagioclase, white mica and biotite, whereas an earlier S_1 fabric is preserved as inclusion trails of epidote and as deformed white mica and biotite porphyroblasts locally oblique to S_2.

Sample 265LS2 is an intermediate felsic tuff consisting of quartz–plagioclase–white-mica–biotite–amphibole–K-feldspar and occurs interlayered with EPMS psammites (Plate 3A). It contains embayed quartz and subhedral plagioclase phenocrysts up to ~3 mm, with minor K-feldspar. Phenocrysts are enveloped by a foliation defined by aligned quartz, white mica, amphibole and biotite. Amphibole is partially replaced by chlorite along cleavage planes, whereas plagioclase and K-feldspar are variably replaced by randomly oriented, euhedral white mica.

Sample 305LS2 (Plate 1F) is a pegmatite dyke composed of quartz–white mica–plagioclase ± K-feldspar. The dyke crosscuts the orthogneiss and white-mica-rich psammite, and it is folded by pre-F_3 structures along with adjacent granite dykes.

U–Pb GEOCHRONOLOGY

Concordia and Kernel Density Estimation diagrams for the individual samples are presented in Figures 2, 3 and 5. Adaptive kernel bandwidth is defined according to Abramson (1984) algorithm. Single dates were calculated using $^{206}Pb/^{238}U$ for grains younger than 1100 Ma and $^{207}Pb/^{206}Pb$ for grains older than 1100 Ma. The complete list

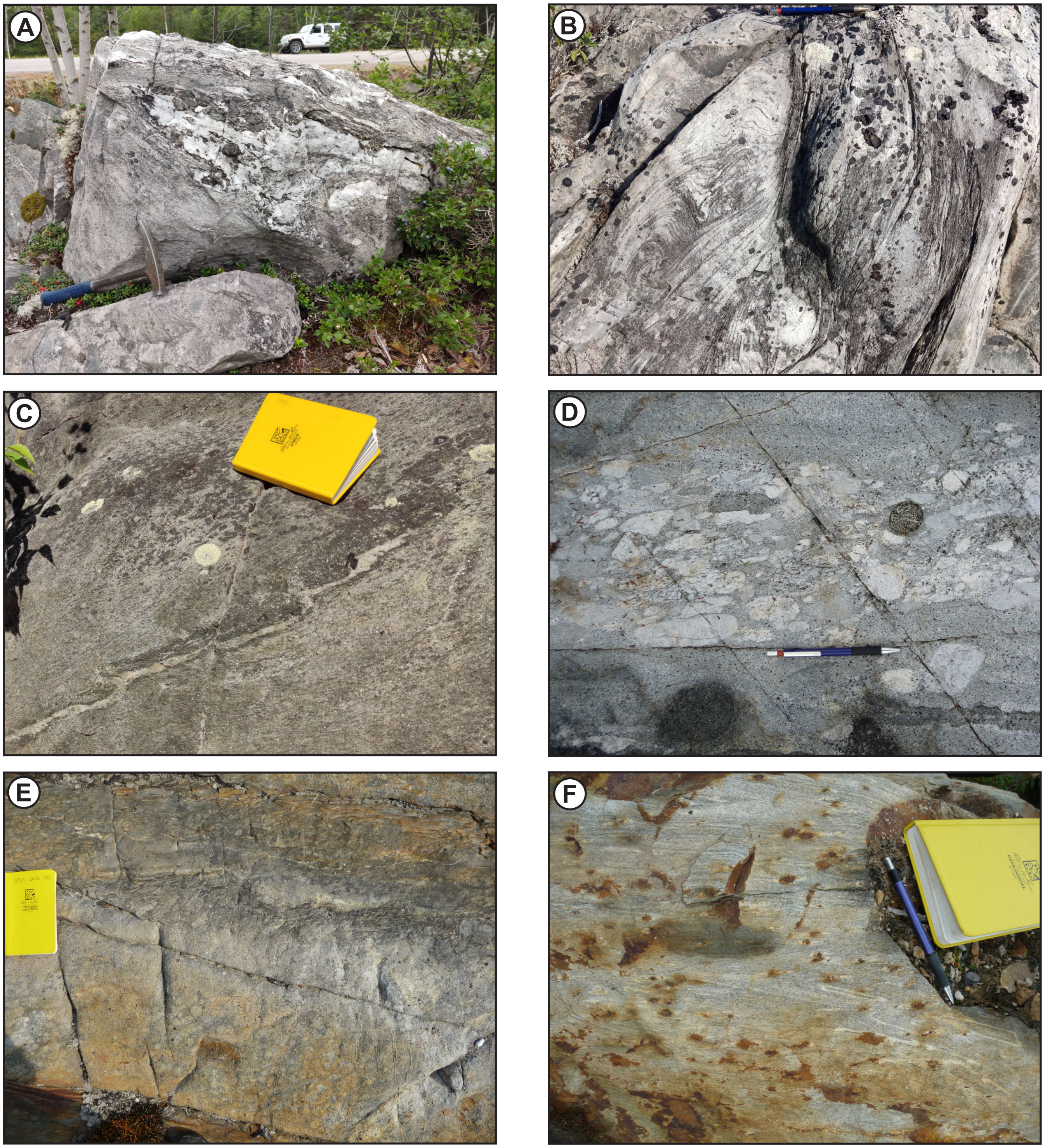

Plate 2. *Representative field photographs. A) Pegmatite dyke, composed of quartz–white mica–plagioclase ± K-feldspar, intruding orthogneiss and white mica-rich psammite and folded by pre-F_3 recumbent isoclinal folds; B) Felsic tuff with deformed and laminated beds; C) White mica-rich psammite, interlayered with pelite beds; D) Polymictic Middle Arm Metaconglomerate marking the base of the EPMS psammites; E) Low-strain EPMS psammite, showing partial Bouma sequences, load casts, flame structures and rip-up clasts (bottom centre); F) EPMS psammite with disseminated sulfides adjacent to northeast–southwest albitized shear zones.*

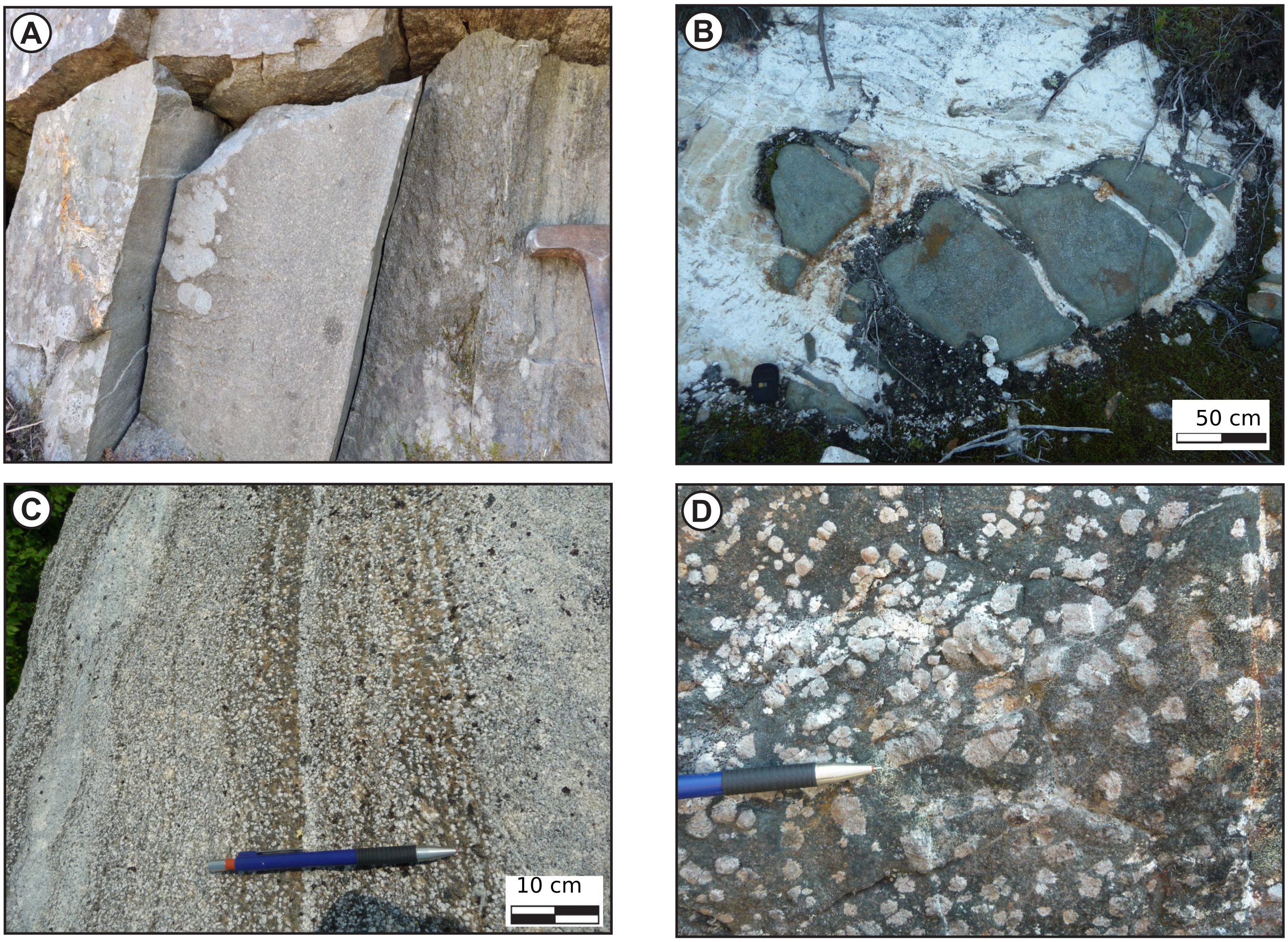

Plate 3. *Field photographs illustrating EPMS (A, B) and OHCG representative lithologies (C, D). A) Layering-parallel mafic boudin within EPMS psammite, preserving eclogite- to amphibolite-facies assemblages and locally associated with quartzite and volcanic layers; B) Late pegmatite dyke crosscutting EPMS psammite and a mafic boudin; C) Bedded OHCG psammite recording pervasive albite porphyroblasts growth; D) Albite-rich amphibolite boudin within the OHCG, with albite porphyroblasts up to 4 cm in diameter.*

of sample details and analytical data are reported in the included supplementary data. All dates are reported at the 2σ confidence interval.

Sample 136LS1: Psammite

Most of the zircon grains from this sample are rounded and display a variety of internal structures revealed with CL imaging, often showing reworked older cores rimmed or embayed by later zircon growth phases (Figure 4A). Of the 90 U–Pb zircon analyses, 57 concordant and near-concordant (<10% discordant) grains range from *ca.* 564 to *ca.* 1978 Ma (Figure 3A), with most of the data defining a main peak at *ca.* 1000 Ma and a subsidiary peak at *ca.* 920 Ma (Figure 2). This main late Mesoproterozoic and Neoproterozoic population has generally rounded shape locally preserving Tonian rims characterized by faint zoning or homogeneous structure, enveloping Mesoproterozoic cores (Figure 4). The rest of the Mesoproterozoic and the Paleoproterozoic grains define two major age groups (Figures 2 and 3) at *ca.* 1300 and *ca.* 1600 Ma. While this age range includes concordant analyses at 1535 ± 29 and 1680 ± 34 Ma, the majority of the data are discordant, hence, the spread of data could also be interpreted as lying on a discordia line with an upper intercept at 1746 ± 44 Ma and a Tonian lower intercept at 960 ± 42 Ma (MSWD = 7.5; n=7; Figure 3B). The two youngest detrital grains yielded a concordia date of 565 ± 14 Ma (MSWD = 1.3; n=2). These spot analyses are from: i) the homogeneous core of a prismatic, subhedral grain, surrounded by a patchy, bright zoned rim (spot analysis #56; Figure 4A); ii) a rounded, fractured grain displaying magmatic zoning (spot analysis #57; Figure 4A).

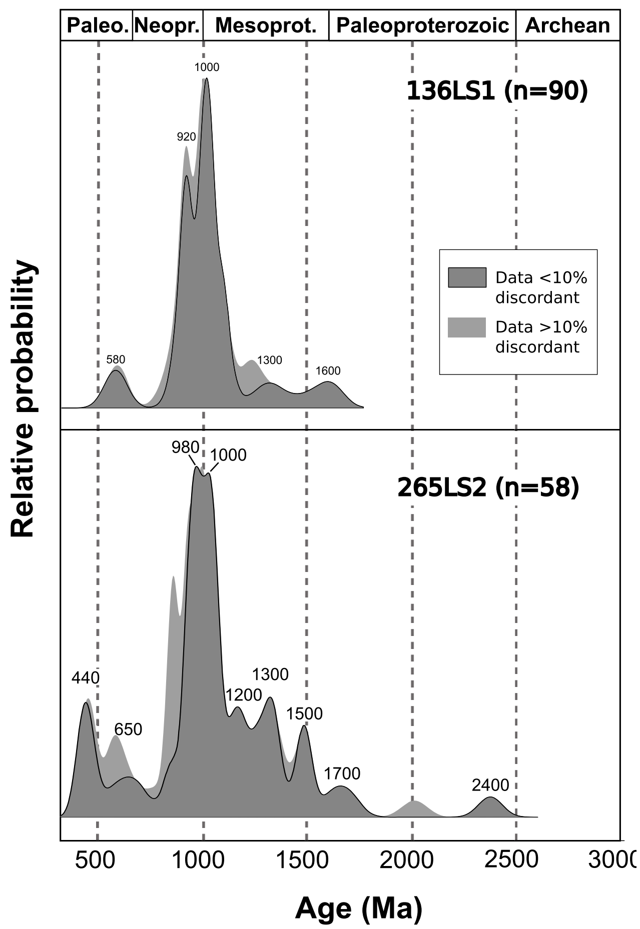

Figure 2. *Kernel density estimate (KDE) diagrams for samples 136LS1 and 265LS2. Dashed vertical lines mark 500 Ma intervals. The area under the continuous line includes only analyses with >90% concordance, whereas the light-grey filled curves incorporate all analyses. Peak dates for each sample correspond to analyses with >90% concordance. KDEs were corrected for common Pb (Stacey and Kramers, 1975) and calculated using $^{206}Pb/^{238}U$ dates for grains <1100 Ma and $^{207}Pb/^{206}Pb$ dates for grains >1100 Ma. Analytical data are provided in the electronic supplemental material.*

Sample 265LS2: Intermediate Tuff

Analyzed zircon grains yielded dates in the range of *ca.* 2691 to *ca.* 420 Ma (58 analyses) with a significant gap in the Paleoproterozoic between *ca.* 2400 and *ca.* 1700 Ma (Figure 2). The dominant population, comprising 48% of the grains, defines a continuous array along concordia with dates of 1200–900 Ma (Figure 3C), and defines two main peaks at *ca.* 980 Ma and *ca.* 1000 Ma (Figure 2). The oldest nearly concordant grain (5% discordant) yielded a $^{207}Pb/^{206}Pb$ date of 2691 ± 27 Ma (Figure 4B). Most Precambrian grains are round, elongate or equant, with patchy or magmatic bright CL zoning (Figure 4B). Twelve analyses define 4 peaks on the probability plot at *ca.* 1750, 1500, 1300 and 1200 Ma (Figure 2). Most analyses, except those close to the 1500-Ma peak, are discordant. Six analyses trend along a discordia with an upper intercept of 2828 ± 96 Ma and a lower intercept of 1492 ± 34 Ma (MSWD = 2.0; Figure 3D); whereas ten analyses define a younger discordia line with intercepts at 1562 ± 56 and 456 ± 311 Ma (MSWD = 2.7; Figure 3E). Several analyses that constrain the lower intercept of the older discordia also define the upper intercept of the younger one and include a core–rim pair on a single zircon grain: the more concordant core lies near the older upper intercept; whereas the rim falls along the younger discordia toward its lower intercept. This relationship, together with overlap between the two regressions, may reflect Pb-loss during a common Mesoproterozoic event (*e.g.*, de Wit and Armstrong, 2014; *this study*) at *ca.* 1560–1490 Ma, with possible later disturbance, although the spread in dates could also represent a mixture of detrital components with varying degrees of discordance. Two grains (<5% discordant) dated at 649 ± 21 and 576 ± 22 Ma define an Ediacaran subsidiary peak. The youngest population is identified from 4 analyses done on low-U, homogeneous, euhedral grains and rims (Figure 4B) that yielded dates between 469 ± 14 and 419 ± 10 Ma.

Sample 305LS: Pegmatite

U–Pb analyses with <10% discordance are divided into three age groups (Figure 5). The oldest group is defined by a discordia model-1 regression (Ludwig, 2003) with an upper-intercept date of 1497 ± 57 Ma and a lower intercept of 552 ± 30 Ma (MSWD = 3; n = 12; Figure 5A). Grains in this group include igneous growth-zoned magmatic cores that are variably mantled or embayed by metamorphic rims (Figure 4C). The second cluster ranges from 1010 ± 19 to 868 ± 20 Ma, with a main subset yielding a weighted mean date of 944 ± 14 Ma (MSWD = 3; n = 4; Figure 5B) after excluding three analyses that diverge from the weighted mean. These grains are generally featureless in CL (Figure 4C), which is consistent with zircon growth or recrystallization during metamorphism (Hanchar and Miller, 1993), although some grains preserve internal zoning. The youngest cluster comprises zircons with low U and yields a weighted mean date of 468 ± 4.3 Ma (Figure 5C). This population is interpreted to reflect zircon growth during Ordovician metamorphism associated with the Taconic orogenic cycle.

DISCUSSION

AGE GROUPS AND TEMPORAL TRENDS

The oldest Neoarchean grain dated at *ca.* 2691 Ma is consistent with Archean populations documented in correla-

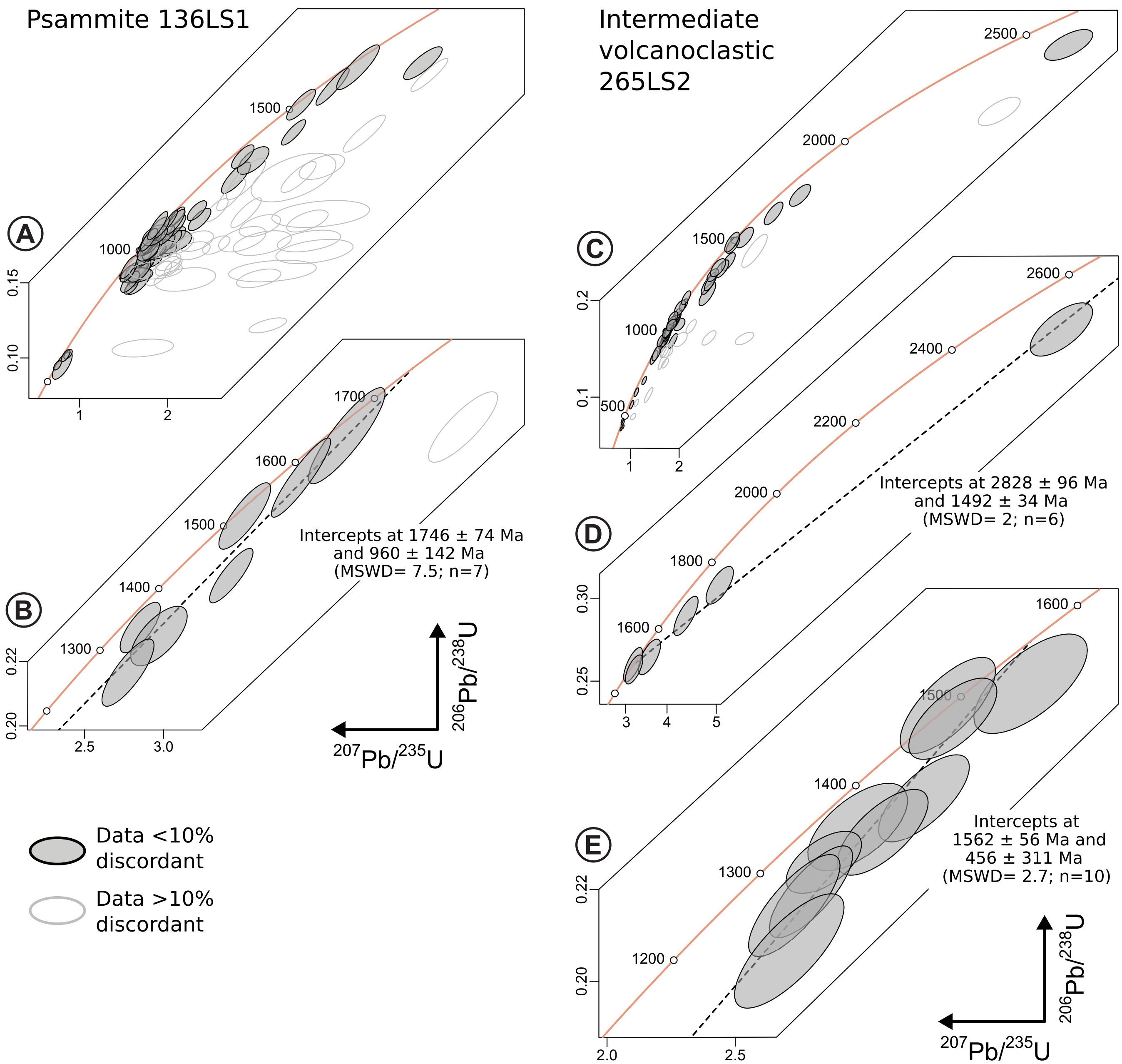

Figure 3. *Concordia diagrams for samples 136LS1 and 265LS2. Solid circles represent analyses with >90% concordance, whereas open circles represent analyses with <90% concordance. The open circle in panel (B) marks one data point excluded from the regression. A) Complete dataset for sample 136LS1; B) Detailed plot for sample 136LS1 showing late Palaeoproterozoic to early Mesoproterozoic zircon analyses; C) Complete dataset for sample 265LS2; D) Detailed plot for sample 265LS2 showing Neoarchean to early Palaeoproterozoic zircon analyses; E) Detailed plot for sample 265LS2 showing early Palaeoproterozoic to Mesoproterozoic zircon analyses. Error ellipses are shown at the 2σ confidence level. Analytical data are provided in the electronic supplemental material.*

tives of the lower FdLS units (Cawood and Nemchin, 2001), and may indicate a source in the Superior Province. The discordant U–Pb dates of magmatic zircon grains from the pegmatite sample (1497 ± 57 Ma; 2σ) overlaps within uncertainty with the orthogneiss derived from a 1491 ± 14 Ma (2σ) syenite gneiss (de Wit and Armstrong, 2014) and is similar in age to many pre-Grenvillian granites of the Long Range Inlier as in the Pinwarian rocks of the Long Range (Heaman *et al.*, 2002). However, the presence of a Tonian population (*ca.* 944 ± 14 Ma), including a subset of grains preserving internal zoning indicates that zircon growth or recrystallization during this interval may also have occurred.

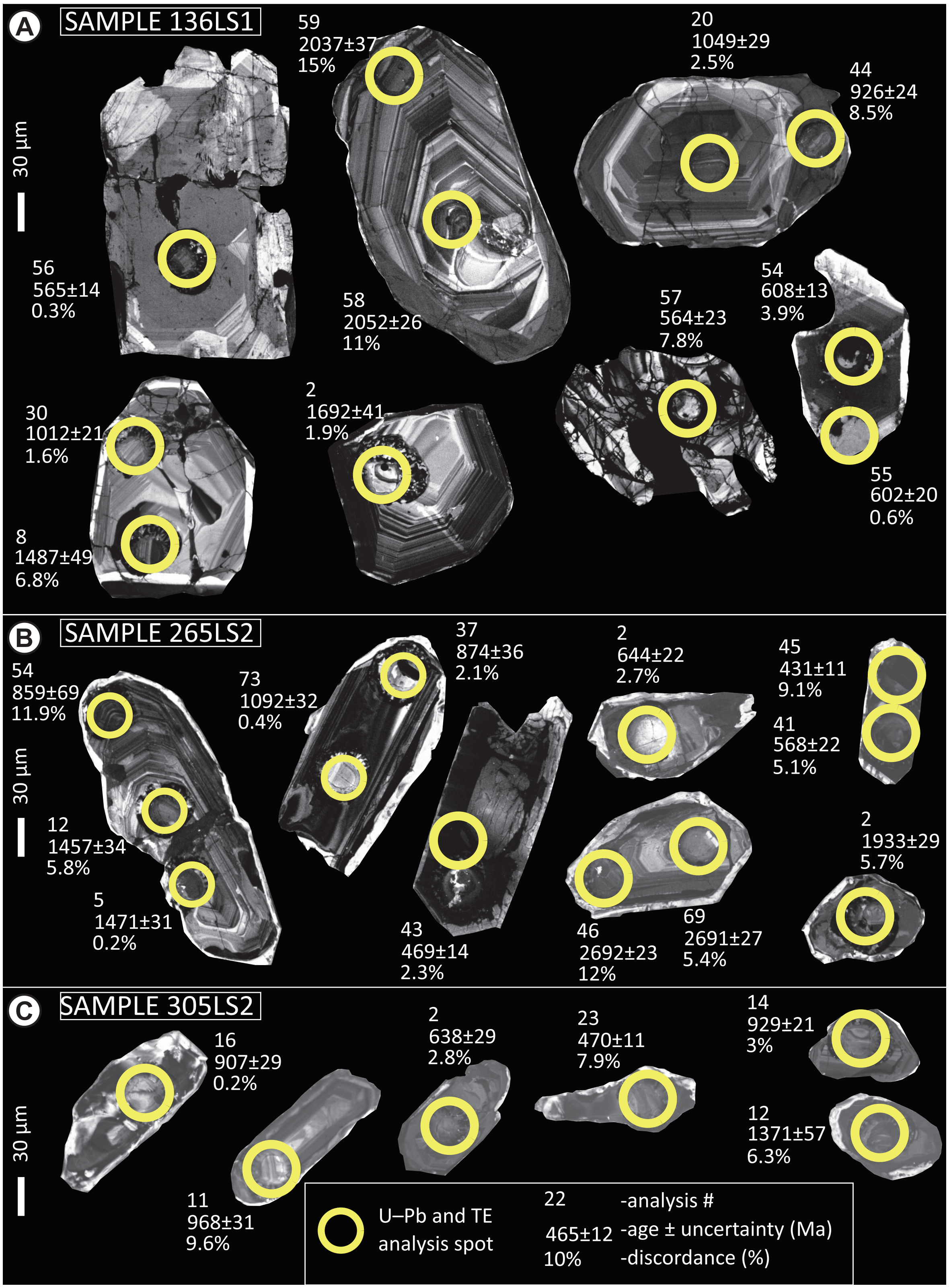

Figure 4. *Cathodoluminescence images of detrital zircon for samples 136LS1 (A) and 265LS2 (B) and zircons from pegmatite sample 305LS2 (C). Dates associated with each spot analysis were calculated using $^{206}Pb/^{238}U$ for grains younger than 1100 Ma and $^{207}Pb/^{206}Pb$ for grains older than 1100 Ma. For analyses where $^{206}Pb/^{238}U$ dates were <1100 Ma but $^{207}Pb/^{206}Pb$ dates were >1100 Ma, the appropriate isotopic ratio was selected based on the single-grain concordia date (Ludwig, 2003).*

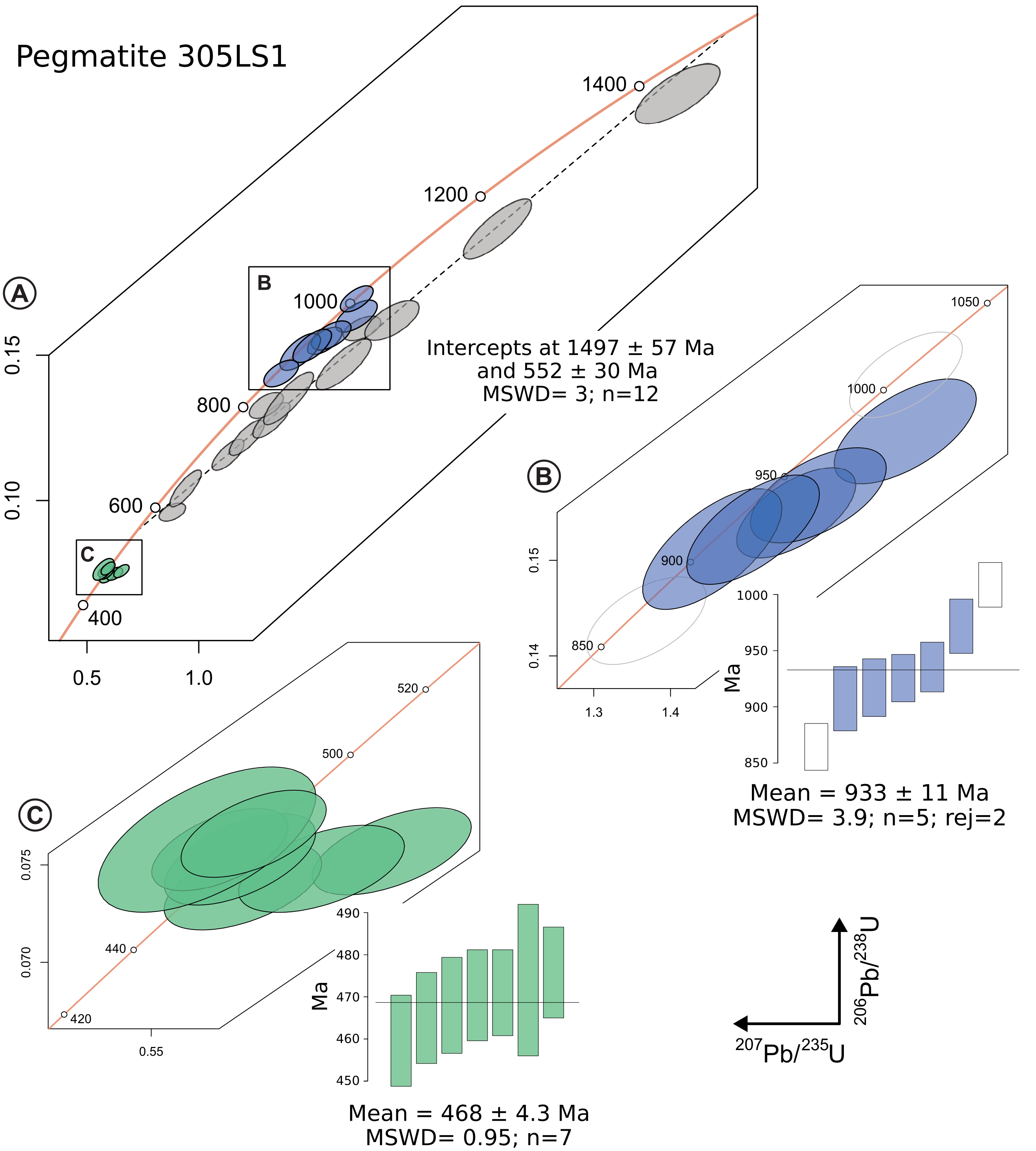

Figure 5. *Concordia diagrams for sample 305LS2. The data shown are >90% concordant. A) Complete dataset for sample 305LS2; B) Concordia and weighted mean diagrams for the Tonian zircon population. Open circles represent data excluded from date calculation; C) Concordia and weighted mean diagrams for the Ordovician zircon population. Error ellipses are shown at the 2σ confidence level. Analytical data are provided in the electronic supplemental material. Weighted mean diagrams show $^{206}Pb/^{238}U$ dates.*

Consequently, although the Mesoproterozoic upper intercept age is consistent with a Pinwarian protolith, the available data do not uniquely distinguish between inheritance from older crust and a potential Tonian magmatic event. The Mesoproterozoic detrital zircon grains with concordant dates at *ca.* 1750 Ma in sample 265LS2, are similar to those from pre-Pinwarian crust in the Long Range Inlier basement rocks (Heaman *et al.*, 2002) and in the banded grey gneiss of the EPMS (de Wit and Armstrong, 2014). The rest of the Mesoproterozoic detrital zircon groups dated at *ca.* 1200, 1300, 1500 and 1750 Ma are also found in other correlative units of the FdLS units (Cawood and Nemchin, 2001). The presence of detrital zircons with Grenvillian (*ca.* 1 Ga) and Pinwarian (*ca.* 1497 Ma) ages, together with grains recording a Tonian (*ca.* 933 Ma) overprint, is consistent with several regional datasets. These include U–Pb zircon dates from pegmatite sample 305LS2, late Grenvillian granitic suites in the Long Range (Heaman *et al.*, 2002), and granite intrusions of the Pine Pond Succession (Strowbridge *et al.*, 2022).

The two EPMS psammite samples analyzed (136LS1 and 265LS2) yield indistinguishable youngest single-grain dates (565 ± 15 Ma and 576 ± 22 Ma, 2σ). Because neither sample contains a coherent youngest cluster, we adopt a conservative unit-level maximum depositional date of ≤565 ± 15 Ma (2σ), defined by the youngest single grain. This date overlaps within error with the 546 ± 18 Ma (2σ) detrital U–Pb zircon date from the host rocks of the Notre Dame arc (east of the BVBL; Zagorevski *et al.*, 2024) and is consistent with MDA estimated for correlatives of FdLS units (Cawood and Nemchin, 2001). The detrital zircon spectra obtained here – including prominent Tonian and Mesoproterozoic populations – closely match those documented for the Baie Verte Margin by Zagorevski *et al.* (2024), who demonstrated that EPMS and FdLS units share a coherent Laurentian provenance distinct from the Humber Margin. These observations are consistent with the possibility that the EPMS includes an Ediacaran volcano-sedimentary component sourced from rocks similar to the nearby basement. Accordingly, if an Ediacaran depositional component is present, deposition of at least part of the volcano-sedimentary sequences constituting the EPMS may record episodes of rifting, potentially related to the opening of the Iapetus and the Taconic seaway (*e.g.*, Waldron and van Staal, 2001; van Staal *et al.*, 2013). The youngest Ordovician dates are interpreted to be metamorphic because of their distinctive euhedral morphology and because they form dark, homogeneous grains in CL or rims enveloping magmatic cores (Figure 4). Their dates of 472–460 Ma are consistent with Ordovician dates associated with burial, high pressure metamorphism, and exhumation of the Baie Verte Margin during the Taconic orogenic cycle (Castonguay *et al.*, 2014; de Wit and Armstrong, 2014; Scorsolini *et al.*, 2025b).

SUMMARY OF DEFINING LITHOLOGICAL ASSOCIATIONS AND PROPOSED NOMENCLATURE

Our new field relationships and U–Pb data allow us to resolve key ambiguities in the definition of the FdLS basement highlighted by previous workers. In particular, we distinguish between a potentially older, polyphase crystalline complex at the lowest structural level of the margin and an overlying Neoproterozoic volcano-sedimentary succession, suggesting that not all rocks previously assigned to the EPMS share the same tectonostratigraphic position.

The lowest structural level of the Baie Verte Margin comprises distinctive rock associations: pink granite gneiss (syenogranite), metamonzogranite, deformed pegmatite, paragneiss/orthogneiss, banded grey gneiss and eclogite boudins overprinted to greenschist, together with felsic tuffs and thick pelitic layers. Metasyenogranite and Qz–Wm–Pl–Kfs pegmatite intrusions yield discordant U–Pb zircon dates with an upper intercept at *ca.* 1500 Ma and record pre-D2 deformation events. The EPMS comprises a basal conglomerate, bedded psammites with thin pelite beds interlayered with minor volcanoclastic rocks and late pegmatite intrusion at *ca.* 451 Ma (Scorsolini *et al.*, 2025b). The similarity between EPMS detrital zircon age spectra and those of the syenite gneiss and pegmatite suggests that the EPMS sediments were derived from sources consistent with the underlying basement rocks of the Baie Verte Margin and with Laurentian basement rocks elsewhere in the Humber Margin (*e.g.*, Long Range Inlier). The new detrital zircon youngest single-grain dates (*ca.* 565 Ma) support the hypothesis that the EPMS may include an Ediacaran volcano-sedimentary succession, structurally overlying, and not part of the reworked underlying Mesoproterozoic basement. Because the rocks exposed at the lowest structural levels preserve lithological associations that differ markedly from the overlying sedimentary and volcaniclastic successions, and yield zircon ages indicating magmatic protoliths and metamorphic overprints that may predate EPMS deposition, we interpret these rocks as a distinct unit, the MABC, representing the lowest structural level of the Baie Verte Margin architecture.

Recent detrital zircon data from the Long Range Inlier reveal that parts of the Humber Margin basement include Tonian–Ediacaran metasedimentary sequences (MDA 996 ± 26 and 906 ± 7 Ma; Hinchey *et al.*, 2025), demonstrating that Laurentian basement in western Newfoundland is far more heterogeneous than previously thought. The banded grey gneiss – here assigned to the Middle Arm Brook Complex (MABC) – lacks the Tonian overprint and preserves a distinctly older Mesoproterozoic signature (de Wit and Armstrong, 2014), provides an analogous example within our study area and supports the interpretation that the MABC represents a composite basement assemblage comparable in complexity to the Long Range Inlier. Therefore, the distribution of detrital zircon dates from the MABC appears to be different from that of the overlying EPMS psammite and volcaniclastic sequences, which contain abundant Tonian detritus. This is consistent with our revised tectonostratigraphy, in which the MABC forms the basement and the EPMS constitutes a distinct Neoproterozoic cover sequence. While the exact nature of the boundary between the MABC and the EPMS is uncertain, the presence of ultramylonites near its inferred position is consistent with an unconformable basement–cover contact that has been tectonically reworked during subsequent tectonometamorphic events.

A km-scale, strongly schistose and albitized shear zone marks the tectonic contact between the EPMS and the overlying OHCG. Field observations indicate that such a high-strain zone develops within rocks at the contact between the two units, rather than constituting a separate unit. Hence, we propose Bear Cove Road Shear Zone as the formal name of this tectonic boundary.

CONCLUSIONS

New field relationships and preliminary U–Pb zircon data allow the redefinition of the Baie Verte Margin architecture. The lowest structural levels comprise Mesoproterozoic to Neoproterozoic orthogneisses with screens of metasedimentary and volcanic rocks that can be distinguished from the overlying EPMS, which contains an Ediacaran volcano-sedimentary cover sequence with strong Tonian detrital zircon signatures. We therefore formalize this basement assemblage as the MABC. Together, the MABC and EPMS constitute the lower structural levels of the Baie Verte Margin; whereas the OHCG is tectonically emplaced atop this architecture across the newly named Bear Cove Road Shear Zone. The field and geochronological constraints presented here suggest that the MABC may represent the Baie Verte equivalent of pre-Dalradian basement units in the Grampian terrane; whereas the EPMS could share provenance and depositional characteristics with Tonian–Ediacaran Dalradian successions. Although preliminary, these correlations provide a useful framework for ongoing work and mineral exploration and highlight the broader North Atlantic significance of resolving the tectonostratigraphy of the Baie Verte Margin.

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