Bird River Greenstone Belt: Stratigraphic Setting and Depositional Environment of Neoarchean Supracrustal Rocks

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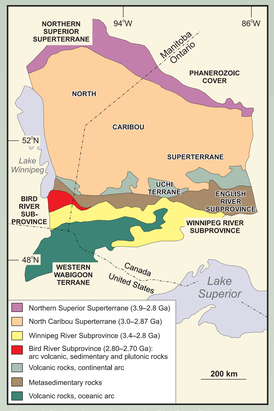

Figure 1: Regional map showing the Bird River Belt and geological subprovinces in western Superior Province.

Introduction

The Neoarchean Bird River Belt (BRB) in southeastern Manitoba is part of an east-trending supracrustal belt that extends for 150 km from Lac du Bonnet in the west to Separation Lake (Ontario) in the east (***Figure 1***). The BRB is host to both a nickel-sulphide development-bearing peridotite resource (TANCO mine) as well as base and platinum group metal ore deposits at the Maskwa-Dumbarton mine west of Bird Lake (***Figure 2***), where additional mineral resources are currently under development. In support of ongoing exploration and development (e.g., Makwa Project, Mustang Minerals Corp., 2011), the Manitoba Geological Survey (MGS) carried out a collaborative mapping project (2005-2008) in the BRB involving detailed stratigraphic mapping, geochemical investigations and focused research projects by post-graduate students at the University of Waterloo. Publications based on this mapping include a 1: 50 000 scale compilation map of the BRB with extensive notes, based on 2005-2007 mapping (Gilbert et al., 2008), two 1: 20 000 scale preliminary maps of the Bird River belt (Gilbert 2008; Gilbert and Kremer 2008) and more detailed 1: 10 000 scale geological maps (Kremer and Lin, 2006; Mealin, 2006).

Late intrusive rocks

Granite, pegmatite, granodiorite, tonalite, quartz diorite
– (TANCO pegmatite *2640 ±7 Ma(1)*; Marijane Lake pluton *2645.6 ±1.3 Ma(2)*
Granitoid pegmatite, post-shear *2647.4 ±1.0 Ma(2)*; Granitoid pegmatite, shear-zone hosted *2650.7 ±0.2 Ma(2)*
Lac du Bonnet Batholith *2660 ±3(3) Ma*; Lac du Bonnet leucogranite *2705 ±6 Ma*; (Cerny, unpublished data)

Diabase, gabbro and andesitic to dacitic intrusive rocks

Sedimentary rocks

FLANDERS LAKE FORMATION *2697 ±18 Ma(4)*
Lithic arenite, polymictic conglomerate

Fault, inferred

BOOSTER LAKE FORMATION *2712 ±17 Ma(4)*
Greywacke-siltstone turbidite, conglomerate

Fault, inferred

Intrusive rocks

SYNVOLCANIC INTRUSIONS
Gabbro, diorite, quartz-feldspar porphyry; granodiorite
(Birse Lake pluton *2723.2 ±0.7 Ma(2)*; Maskwa Lake Batholith II *2725 ±6 Ma(3)*; Pointe du Bois Batholith *2729 ±8.7 Ma(3)*)
TANCO gabbro *2723.1 ±0.8 Ma(2)*

Metavolcanic and metasedimentary rocks

Bird River Belt north panel
DIVERSE ARC ASSEMBLAGE *2706 ±23 Ma(5)*
Basalt, andesite, rhyolite, related fragmental and intrusive rocks; heterolithic volcanic fragmental rocks; greywacke-siltstone turbidite, chert, iron-formation; polymictic conglomerate (contains clasts derived from Bird River Sill)

PETERSON CREEK FORMATION *2731.1 ±1 Ma(2); 2734.6 ±3.1 Ma(5)*
Rhyolite, rhyolite (massive to fragmental); felsic tuff and heterolithic felsic volcanic fragmental rocks

Bird River Belt south panel
BERNIC LAKE FORMATION *2724.6 ±1.1 Ma(2)*
Basalt, andesite, dacite and rhyolite (massive to fragmental); related intrusive rocks and heterolithic volcanic fragmental rocks

Unconformity/Fault

Intrusive rocks

BIRD RIVER SILL *2744.7 ±5.2 Ma(3)*
Dunite, peridotite, picrite, anorthosite and gabbro

Metavolcanic and metasedimentary rocks

MORB-type VOLCANIC ROCKS
Basalt (aphyric to plagioclase-phyric; locally pillowed, amygdaloidal or megacrystic); related volcanic breccia; oxide-facies iron formation

Fault, inferred

EAGLENEST LAKE FORMATION
Greywacke-siltstone turbidite

Older intrusive rocks

Granodiorite, diorite (Maskwa Lake Batholith I *2782 ±11 Ma(3); 2832.3 ±0.9 Ma(2), 2852.8 ±1.1 Ma(2), 2844 ±12 Ma(3)*)

References for geochronological data: (1) Baadsgaard and Cerny, 1993; (2) Gilbert et al., 2008; (3)Wang, 1993; (4) Gilbert, 2006; (5) Gilbert, unpublished data, 2007

Figure 1: Principal geological formations, their ages and contact relations in the Bird River Belt.

In 2011, Eric Yang (MGS) renewed mapping north of the main part of the greenstone belt, in an area 30 km northwest of Bird Lake (Yang et al., 2011; see poster T 16). The map area, located in the northern part of the greenstone belt, contains the mafic-ultramafic Mayville intrusion that is the target of exploration for base and platinum group metals by Mustang Minerals (Mayville Property, Mustang Minerals Corp. 2012). This poster focuses on the main part of the Bird River Belt and provides a brief outline of its subdivision into north and south panels of continental arc type rocks and flanking back-arc/ocean-floor components. The main topic of the poster is the stratigraphy and depositional setting of the arc-type formations in the north panel, and their contact relationships with penecontemporaneous orogenic sedimentary rocks that extend through the central part of the greenstone belt.

Regional setting and geology of the Bird River Belt

The BRB occurs in a transitional oceanic to continental-margin setting between flanking older cratonic blocks to the north and south (***Figure 1*** and 3). Continental-arc magmatism and orogenic sedimentation in the Bird River Subprovince spanned approximately 100 Ma (2.80–2.70 Ga; Percival et al., 2006). North panel rocks-Peterson Creek Formation (PCF, ***Table 1***) and Diverse Arc assemblage (DAA)-are compositionally akin to arc volcanic rocks at active continental margins, whereas volcanic rocks in the south panel (Bernic Lake Formation) appear to document incipient rifting of the continental-arc rocks (Gilbert et al., 2008). Mid-ocean-ridge basalt (MORB)-type rocks that extend along both the south and north margins of the main BRB are interpreted as relatively older than the arc-type rocks and probably represent ocean-floor/back-arc environments; they are flanked by older cratonic blocks to the south (Winnipeg River Subprovince, 2.8–3.4 Ga) and north (Maskwa Lake Batholith, 2.73–2.85 Ga). A northern arm of arc and MORB-type rocks wraps around the east margin of the Maskwa Lake Batholith (***Figure 2***) and is interpreted to be older than the ca. 2743 Ma Mayville intrusion (V. McNicoll, pers. comm. 2012; Yang, Report GS-3 in the MGS Report of Activities, 2012). The contemporaneous 2745 (±5) Ma Bird River Sill (Wang, 1993) intrudes the Northern MORB-type formation at the north margin of the main BRB arc-type sequence, but is older than the 2.72–2.73 Ga arc-type sequence immediately to the south, which contains conglomerate with gabbroic clasts derived from the sill. The main BRB arc-type sequence thus appears to be younger than the northern arm of the greenstone belt.

Orogenic sedimentation (2712–2697 Ma, Gilbert, 2006) subsequent to continental-arc volcanism resulted in the deposition of turbidites (Booster Lake Formation) and penecontemporaneous fluvial-alluvial deposits (Flanders Lake Formation). The turbidites may be stratigraphically equivalent to the fluvial-alluvial rocks, but relatively more distal from the source terrane. These orogenic sedimentary rocks, which are invariably fault bounded, have been widely assumed to be equivalent to epiclastic deposits and metamorphic derivatives in the west- to northwest-trending English River Subprovince, which lies between the Bird River Subprovince and the Uchi Subprovince to the northeast (***Figure 1, 2*** and ***3***; Hrabi and Cruden, 2006). Subduction-related volcanic activity and orogenic sedimentation came to an end due to collision of the Uchi continental-margin succession with the Winnipeg River Subprovince, which followed 2.72–2.71 Ga convergence of the North Caribou and Winnipeg River cratonic blocks (Lemkow et al., 2006). The tectonic collision was associated with regional deformation, metamorphism and granitoid plutonism.

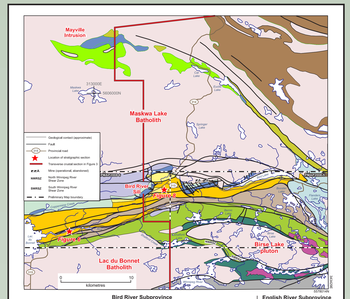

Figure 2: Geology of the area between Winnipeg River and the area north of Cat Lake, showing the main part of the Bird River greenstone belt between Lac du Bonnet and Flanders Lake, and the northern arm extending as far as the Mayville intrusion.

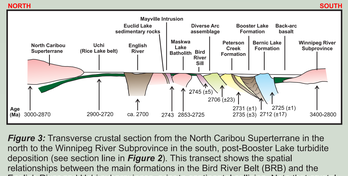

Figure 3: Transverse crustal section from the North Caribou Superterrane in the north to the Winnipeg River Subprovince in the south, post-Booster Lake turbidite deposition (see section line in ***Figure 2***). This transect shows the spatial relationships between the main formations in the Bird River Belt (BRB) and the English River and Uchi subprovinces, prior to continental collision. Note that crustal underplating to the south and deformation of supracrustal rocks assumed to have accompanied convergence of the North Caribou Superterrane and Winnipeg River Subprovince are not indicated, although convergence was probably underway during turbidite deposition (Lemkow et al., 2006). LITHOPROBE studies indicate underplating of the BRB by the Winnipeg River Subprovince to the south, as well as the presence of a subduction zone to the north.

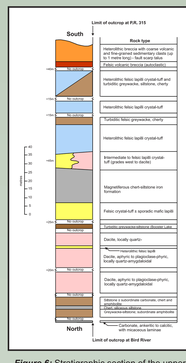

Figure 6: Stratigraphic section of the upper (approximately 350 m) part of the PCF in the western BRB (shown in ***Figure 2***).

Summary of main points

Major findings of the project identified in publications cited above include the following ~

(1) The BRB occurs in a transitional oceanic to continental-margin setting between older cratonic blocks-the North Caribou Superterrane to the north and the Winnipeg River Subprovince to the south.

(2) The predominant arc-type rocks in the BRB are separated into north and south panels by the Booster Lake Formation - a succession of orogenic turbidite deposits. These turbidites occur as a major, fault-bounded enclave and several smaller fault slivers thought to be part of a former elongate rift basin extending laterally for over 40 km through the central part of the greenstone belt.

(3) The south panel arc-type rocks are stratigraphically and geochemically distinct from those in the north panel (Gilbert et al., 2008). In addition to the contrasting geochemical affinities, the two panels are also distinguished by differences in their overall volcanic rock composition: basalt-andesite constitutes over half of the south panel but less than 10% of the north panel, in which rhyolite and dacite make up over 80% of the volcanic rock component.

(4) Late sanukitoid intrusive rocks (+/- associated fragmental deposits) are found in all the volcanic formations within the north panel of the BRB, as well as within the Booster Lake Formation, indicating the youngest volcanic rocks are penecontemporaneous with the Booster Lake turbidite deposits.

(5) Volcanogenic massive sulphide (VMS)-type mineralization has not yet been positively identified in the BRB, but numerous stratigraphically-controlled base metal sulphide occurrences and zones of hydrothermal alteration are positive indicators in favour of the potential for VMS mineralization within the BRB.

Conclusions arising from lithologic and stratigraphic analysis of rocks in the BRB north panel to investigate their depositional setting and history include the following ~

(6) The Peterson Creek Formation (PCF) in the BRB north panel consists very largely of felsic volcanic rocks; massive flows are predominant in the eastern part whereas volcanic fragmental deposits are more widespread in the west (***Figure 4a***, b, c and ***5a***, b). The depositional environment may have been partly subaerial except for the upper part of the formation which contains intercalations of epiclastic rocks, chert and oxide-facies iron formation (***Figure 6***).

(7) A very coarse fragmental deposit at or close to the top of the PCF section may represent a fault scarp talus deposit associated with synvolcanic faulting at the stratigraphic top of the formation (***Figure 7a***, b, c).

(8) The DAA (***Figure 8***) is a suite of volcanic, epiclastic and volcanic exhalative deposits that are of more limited extent compared to the PCF, assumed to reflect the original stratigraphic distribution rather than subsequent faulting that could have removed parts of the stratigraphic record. Most of the DAA appears to be of subaqueous origin; relatively tranquil conditions (e.g., thinly laminated chert and tuffaceous strata) alternated with (possible subaerial) volcanism represented by massive flows, pyroclastic deposits and derived debris flows, locally associated with scouring of the underlying strata (***Figure 9a***, b; ***10a***, b; ***11a***, b). The debris flows incorporated coarse detritus from the substrate, whereas penecontemporaneous turbidites reworked finer grained detritus.

(9) The DAA occurs at several localities at the north margin of the north panel and also locally overlies the PCF in a synclinal fold core southwest of the junction of Provincial Roads 314 and 315 (***Figure 2***). The contact relationships are uncertain but may be gradational; in fact the uppermost PCF volcanic and epiclastic rocks at the south margin of the formation (***Figure 6***) may have been penecontemporaneous with the lower DAA rocks.

(10) A polymictic conglomerate member, interpreted to be at or close to the top of the DAA sequence, contains clasts of all the main stratigraphic units within the north panel, as well as gabbroic fragments from the Bird River Sill and probably derived from the (back-arc) Northern MORB formation (***Figure 12a***, b, c). Deposition of the conglomerate may have been coincident with the onset of rifting, thought to mark the beginning of extensive turbidite deposition (Booster Lake Formation) that extended the length of the Bird River Belt and beyond, in the contiguous English River Subprovince (***Figure 2***).

(11) The fault-bounded Booster Lake Formation (BLF) contains detritus of which the predominant (detrital zircon) age is approximately 2730 Ma - coincident with the 2731-2735 Ma (igneous) age of the PCF (Gilbert, 2006; Gilbert et al., 2008). Locally, the BLF turbidites display textures suggesting the underlying PCF was the source of detritus. The turbidite locally contains abundant coarse fragments of quartz and feldspar resembling those in some PCF crystal tuff, as well as rare cobbles of coarse felsic crystal tuff that are lithologically identical to contiguous PCF deposits (***13a***, b, c, d), suggesting that there was not much transport from the site of erosion nor significant displacement along the faulted contact between the volcanic and sedimentary rocks.

(12) The proposed model implies that the diverse and stratigraphically distinctive DAA rocks were deposited in restricted basins to the north that overlie the lower and central PCF, roughly coincident with marine incursions (turbidite sedimentation and minor iron formation) in the uppermost part of the PCF to the south (see (6) above). Rifting may have resulted in fault scarps (associated with talus deposits - see (7) above) at the inferred, essentially conformable contact between the PCF and younger BLF, at the south margin of the PCF. Local stratigraphic analysis (see (11) above) and the youngest detrital zircon dates from the DAA and BLF (2706 ±23, 2712 ±17 Ma respectively, Gilbert et al., 2008) are consistent with this model.

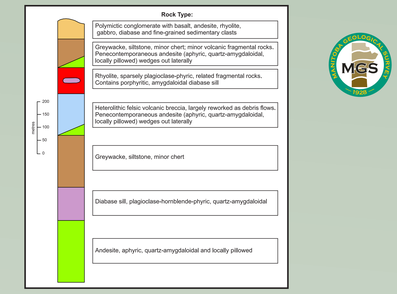

Figure 8: Stratigraphic section of the Diverse Arc assemblage of the north panel, in the central part of the Bird River Belt (shown in Figure 2).

References

Baadsgaard, H. and Cerny, P. 1993: Geochronological studies in the Winnipeg River pegmatite populations, southeastern Manitoba; Geological Association of Canada-Mineralogical Association of Canada, Joint Annual Meeting, Program with Abstracts, v. 18, p. A5.

Gilbert, H.P. 2006: Geological investigations in the Bird River area, southeastern Manitoba (NTS 52L5N and 6); in Report of Activities 2006, Manitoba Science, Technology, Energy and Mines, Manitoba Geological Survey, p. 184-205.

Gilbert, H.P. 2008: Geology of the west part of the Bird River area, southeastern Manitoba (NTS 52L5); Manitoba Science, Technology, Energy and Mines, Manitoba Geological Survey, Preliminary Map PMAP2008-5, scale 1:20 000 (supersedes Preliminary Map PMAP2007-6).

Gilbert, H.P. and Kremer, P.D. 2008: Geology of the east part of the Bird River area, southeastern Manitoba (NTS 52L6); Manitoba Science, Technology, Energy and Mines, Manitoba Geological Survey, Preliminary Map PMAP2008-4, scale 1:20 000 (supersedes Preliminary Map PMAP2007-5).

Gilbert, H.P., Davis, D.W., Duguet, M., Kremer, P.D., Mealin, C.A. and MacDonald, J. 2008: Geology of the Bird River Belt, southeastern Manitoba (parts of NTS 52L5, 6); Manitoba Science, Technology, Energy and Mines, Manitoba Geological Survey, Geoscientific Map MAP2008-1, scale 1:50 000 (plus notes and appendix).

Holzhey, G. 2001: Contribution to petrochemical-mineralogical characterization of alteration processes within the marginal facies of rhyolitic volcanics of Lower Permian Age, Thuringian Forest, Germany; Chemie der Erde v. 61, p. 149-186.

Hrabi, R.B. and Cruden, A.R. 2006: Structure of the Archean English River subprovince: implications for the tectonic evolution of the western Superior Province, Canada; Canadian Journal of Earth Sciences, v. 43, p. 947-966.

Kremer, P.D. and Lin, S. 2006: Geology of the Bernic Lake area around the Tanco mine, Bird River greenstone belt, southeastern Manitoba (NTS 52L6); Manitoba Science, Technology, Energy and Mines, Manitoba Geological Survey, Preliminary Map PMAP2006-9, scale 1:10 000.

Lemkow, D.R., Sanborn-Barrie, M., Bailes, A.H., Percival, J.A., Rogers, N., Skulski, T., Anderson, S.D., Tomlinson., K.Y., McNicoll, V., Parker, J.R., Whalen, J.B., Hollings, P. and Young, M. 2006: GIS compilation of geology and tectonostratigraphic assemblages, western Uchi Subprovince, western Superior Province, Ontario and Manitoba; Manitoba Science, Technology, Energy and Mines, Manitoba Geological Survey, Open File Report OF2006-30, 1 CD-ROM, scale 1:250 000.

Mealin, C.A. 2006: Geology of the Bird River Sill, southeastern Manitoba (part of NTS 52L5); Manitoba Science, Technology, Energy and Mines, Manitoba Geological Survey, Preliminary Map PMAP2006-10, scale 1:10 000.

Mustang Minerals Corp. 2011: Mustang Purchases Bouchard Hebert Mill for Makwa Project, press release, Feb 2 2011, URL http://finance.yahoo.com/news/Mustang-Purchases-Bouchard-iw-4228140680.html.

Mustang Minerals Corp. 2012: Mustang drilling at Mayville property, press release, Sept 12 2012, URL http://www.mustangminerals.com/admin/news/71.pdf

Percival, J.A., McNicoll V. and Bailes, A.H. 2006: Strike-slip juxtaposition of ca. 2.72 Ga juvenile arc and >2.96 Ga continent margin sequences and its implications for Archean terrane accretion, western Superior Province, Canada; Canadian Journal of Earth Sciences, v. 43, p. 895–927.

Wang, X. 1993: U-Pb zircon geochronology study of the Bird River greenstone belt, southeastern Manitoba; M.Sc. thesis, University of Windsor, Windsor, Ontario, 96 p.

Yang, X.M., Gilbert, H.P., Corkery, M.T., Houlé, M.G. 2011: The Mayville mafic-ultramafic intrusion in the Neoarchean Bird River greenstone belt, southeastern Manitoba (part of NTS 52L12): preliminary geochemical investigation and implication for PGE-Ni-Cu-(Cr) mineralization; in Report of Activities 2011, Manitoba Innovation, Energy and Mines, Manitoba Geological Survey, p. 127–142.

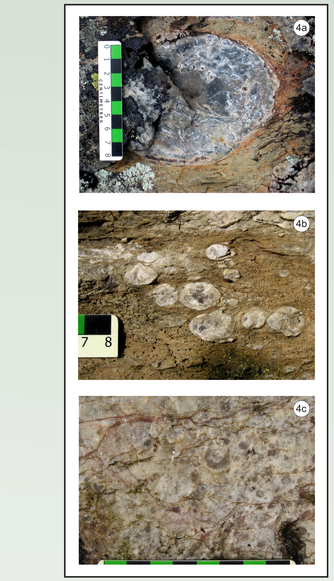

Figure 4: a) Large, silica-rich spherulitic body in an ultra fine-grained sericitic, rhyolite matrix with local vitroclastic texture. Similar textures in Mesozoic rocks have been attributed to 'spherulitic crystallization' in the marginal parts of rhyolitic lava domes (Holzhey, 2001). Associated alteration consists of increase in SiO_2, K, Th, Y, Nb and heavy rare-earth elements (REE), and concomitant depletion of Na, Sr and light REE; b) Smaller spherulites with infilling of internal cavities due to interaction with hydrothermal or meteoric water; c) Peritic texture in rhyolite adjacent to the spherulitic zone.

Figure 5: a) Flow-laminated, partly fragmental rhyolite clast incorporated in a felsic mass flow (PCF); b) Heterolithic felsic fragmental rock attributed to reworking of an original, possibly ignimbritic rhyolite flow. Such rocks are the predominant fragmental facies of the PCF and are widespread in the central and western parts of the formation.

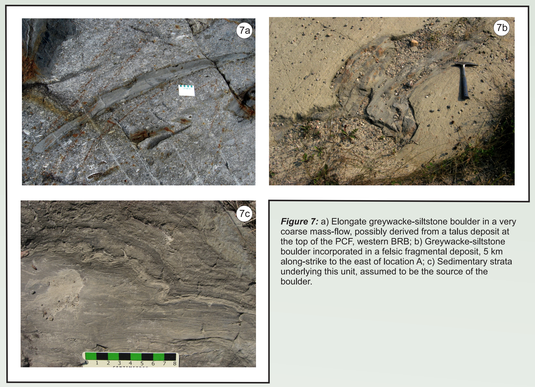

Figure 7: a) Elongate greywacke-siltstone boulder in a very coarse mass-flow, possibly derived from a talus deposit at the top of the PCF, western BRB; b) Greywacke-siltstone boulder incorporated in a felsic fragmental deposit, 5 km along-strike to the east of location A; c) Sedimentary strata underlying this unit, assumed to be the source of the boulder.

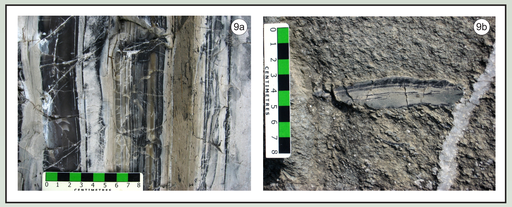

Figure 9: a) Laminated chert (DAA) from an approximately 25 m thick member; b) Laminated chert fragment incorporated in a tuffaceous debris flow.

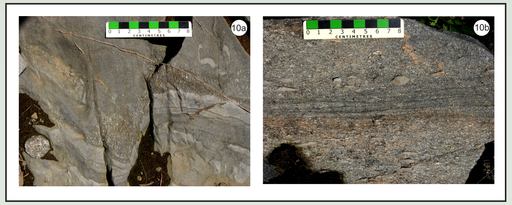

Figure 10: a) Turbidite (DAA) showing scour, rip-ups, graded bedding and syn-sedimentary deformation; b) Intermediate fragmental deposit (DAA) with diffuse parallel lamination, interpreted as either a mass-flow or surge deposit, possibly in a subaerial environment.

Figure 11: a) Rhyolite (DAA) with highly contorted, spherulitic trails; b) Irregular, abraded upper surface of spherulitic rhyolite, overlain by a heterolithic, tuffaceous mass-flow deposit; c) Intermediate, finely bedded tuff (DAA) truncated by an overlying debris flow derived from volcanic fragmental rocks.

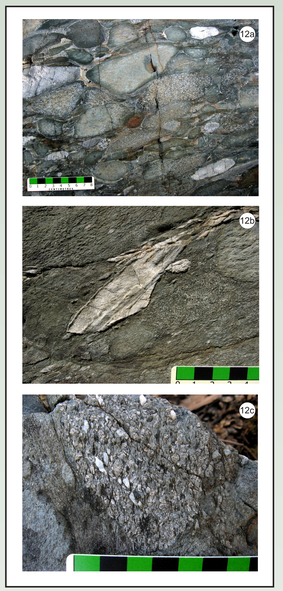

Figure 12: a) Polymictic conglomerate at, or close to, the top of the DAA. Clast types include basalt (a major component of the conglomerate, probably derived from the Northern MORB-type Formation) and gabbro from the Bird River Sill; b) felsic tuff clast derived from the underlying PCF strata; c) porphyritic, quartz-amygdaloidal andesite clast of sanukitoid composition.

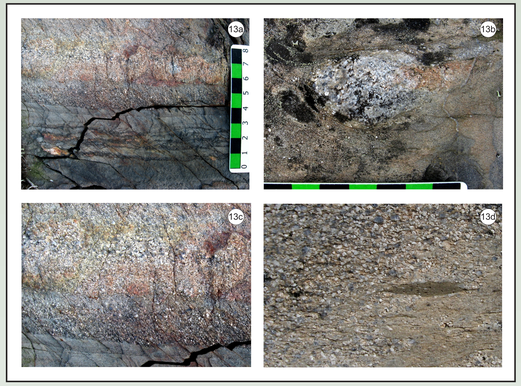

Figure 13: a) Booster Lake Formation turbidite with Bouma zones A, B, and D; b) Booster Lake Formation greywacke with pebble of felsic crystal tuff, probably derived from the PCF. Note that coarse-grained Booster Lake greywacke (c) and PCF crystal tuff (d) are texturally very similar.