Preliminary Activities Report on the depositional history and contact relationships of the Ament Bay Metasedimentary Assemblage, Sturgeon Lake Greenstone Belt, Northwestern Ontario

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Introduction

This report summarizes the field work accomplished for the Metal Earth Sturgeon transect in July 2021. This is the second and final field season for this MSc project, with the first occurring in August 2020. The Metal Earth research initiative focuses on the controlling factors of metal endowment in greenstone belts. This project is supported by the Canada First Research Excellence Fund and is being implemented by the Mineral Exploration Research Centre at the Harquail School of Earth Sciences, Laurentian University, Sudbury Ontario in collaboration with the Department of Geology at the University of Wisconsin-Eau Claire.

The Metal Earth Sturgeon transect intersects the Sturgeon Lake greenstone belt (SLGB) along Highway 599. The goal of this thesis project is to attain an improved understanding of the provenance, depositional history and contact relationships of the Ament Bay Metasedimentary Assemblage (AMBA), a late-orogenic basin in the SLGB (Sanborn-Barrie and Skulski, 2005). To achieve this goal, stratigraphic columns, clast counts, and detailed outcrop maps were completed and samples were collected for geochronology, geochemistry and thin section.

Archean late-orogenic metasedimentary assemblages, such as the ABMA, are important because they may provide insights into terrane amalgamation and the formation of large-scale subprovince boundaries (Mueller and Corcoran, 1998). They are also important regional exploration targets for precious metals in shear zones (Bleeker, 2012). The ABMA is of interest because of its resemblance to the typical Timiskaming-type basins that host economically viable gold deposits in the Abitibi subprovince. Both ABMA and Timiskaming-type basins represent the final geologic stage of their respective greenstone belts, are made up of mostly fluvial-immature clastic rocks, and are spatially associated with calc-alkalic to alkalic magmatism and major fault zones (Hyde, 1980; Thurston and Chivers, 1990; Bleeker, 2012).

Regional Geology

The western Wabigoon Subprovince of the western Superior craton is a granitoid-greenstone terrane composed of mostly Neoarchean mafic- to felsic volcanic and sedimentary successions, and calc-alkalic- to alkalic plutons (fig.1). The Metal Earth Sturgeon transect is located in the easternmost part of the western Wabigoon terrane, and intersects the Neoarchean Savant-Sturgeon Lake greenstone belt along with the Mesoarchean Winnipeg River terrane to the south. The Savant-Sturgeon Lake greenstone belt is bounded by the Winnipeg River terrane to the north and west and by the sedimentary Warclub Assemblage and locally the volcanic-sedimentary Jutten Assemblage to the south and east; the former representing a later stage fore-arc basin and the latter representing a continental margin sequence and the first depositional event in the greenstone belt (Sanborn- Barrie and Skulski, 2006).

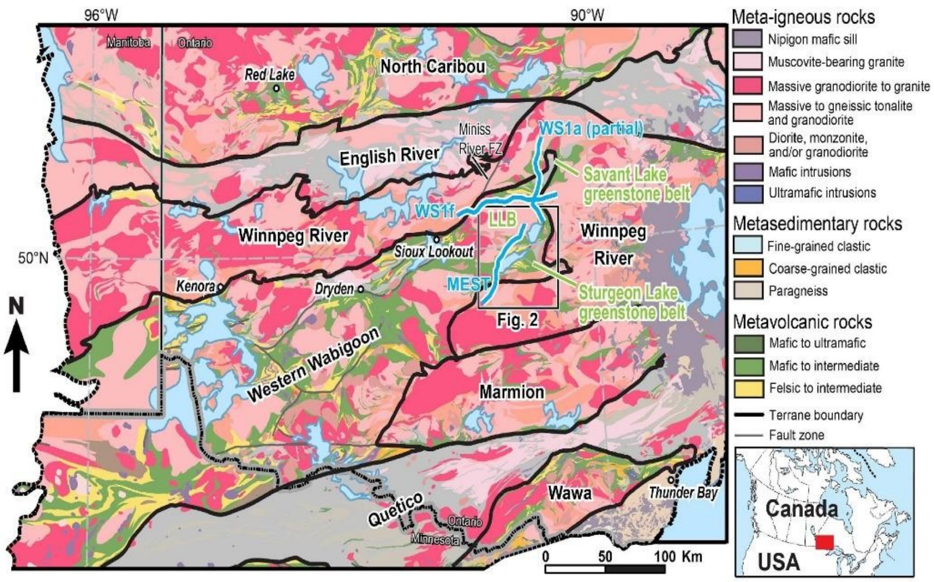

Figure 1. Location of Metal Earth Sturgeon Transect (MEST) in northwestern Ontario. Modified after Montison et al. (2018) and Ma et al. 2021

The SLGB consists of primarily mafic- to felsic volcanic and plutonic rocks as well as terrigeneous clastic assemblages (fig. 2). All rocks in this greenstone belt have been affected by regional metamorphic grades of lower- to upper greenschist facies. The volcanic and sedimentary supracrustal assemblages are exposed within a regional-scale syncline, with the Central Sturgeon and Ament Bay assemblages exposed in the hinge zone, and older supracrustal rocks exposed in the limbs. The Fourbay Assemblage (*circa:* 2775 Ma: Davis, Sutcliffe and Trowell, 1988) occurs in the northern part of the SLGB, and represents the oldest supracrustal assemblage in the Sturgeon transect. This assemblage is a bimodal succession composed of mafic to intermediate flows (locally pillowed) and intermediate to felsic volcaniclastic rocks. The Handy Lake Assemblage (*circa:* 2745 Ma: Sanborn-Barrie and Skulski, 2005) consists of pillowed and massive basalt flows, quartz-phyric felsic flows, and pyroclastic felsic volcanic rocks, which have been intruded by gabbroic dykes/sills (Trowell, 1983; Sanborn-Barrie and Skulski, 2005). The South Sturgeon Assemblage (*circa:* 2735 Ma: Davis et al. 1985) consists of a subaerial to shallow water basaltic shield volcano with varying mafic volcanic facies and a bimodal subaerial to subaqueous caldera complex hosting VMS deposits which were mined between 1972 and 1991 (Morton et al. 1991; Hudak, 2015). The 2721-2718 Ma Central Sturgeon

Assemblage (CSA) consists of mainly mafic volcanic flows with calc-alkalic to tholeiitic affinities, and local intermediate- to felsic rocks (Sanborn-Barrie and Skulski, 2005).

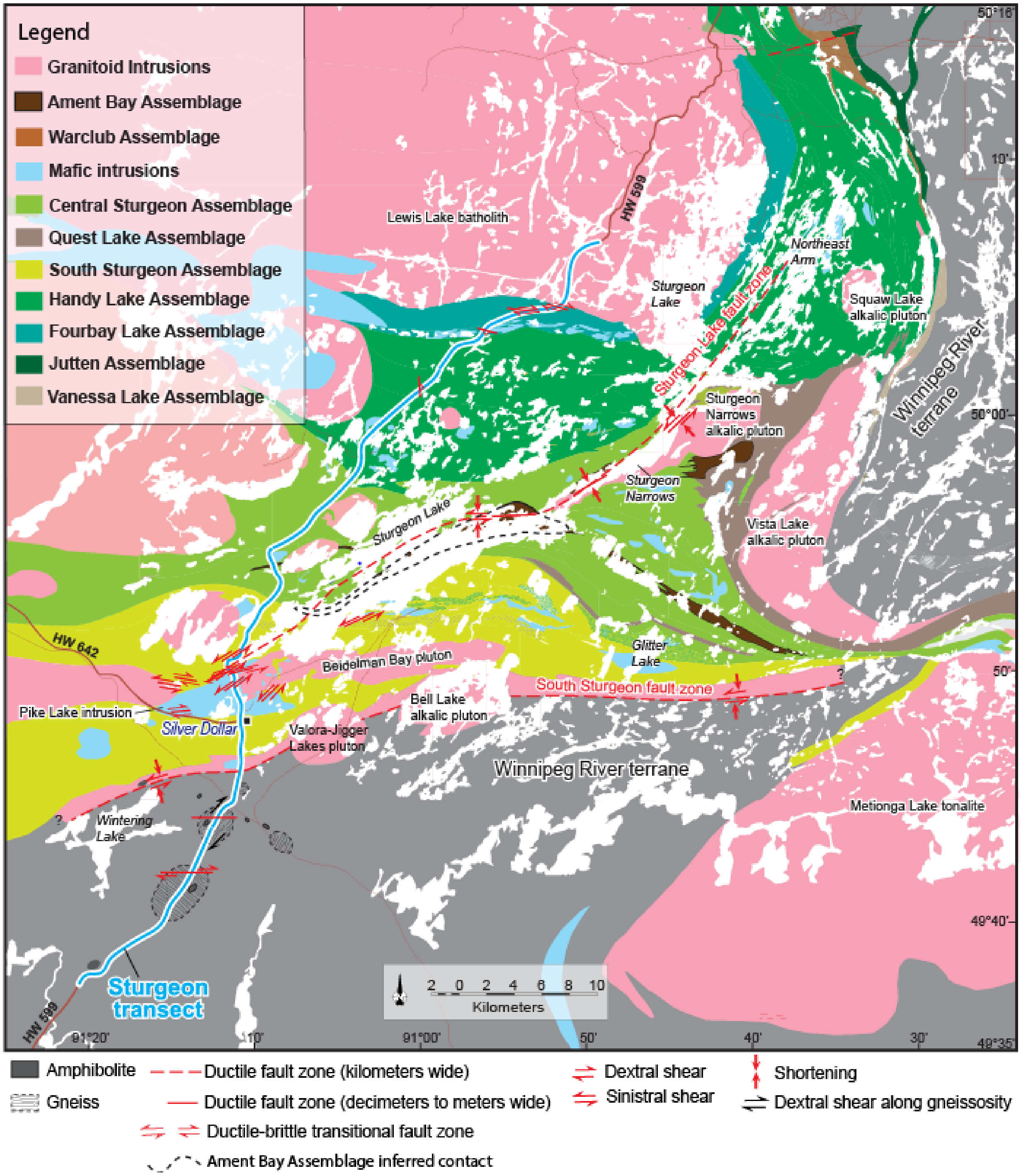

Figure 2. Regional geology of the Sturgeon Lake greenstone belt. Modified after Stone et al. (2002), Sanborn-Barrie and Skulski (2005), and Ma et al. (2021)

The ABMA is exposed in the hinge of the regional syncline and overlies the CSA. It consists of polymictic conglomerate, and arkosic- to lithic arenites and wackes which are interpreted to have fluvial-alluvial and submarine origin (Sanborn-Barrie and Skulski, 2005).

The SLGB also consists of regionally extensive felsic- to intermediate intrusive rocks which are considered synvolcanic, early to syntectonic, and late to post tectonic. Both synvolcanic and early- to syntectonic intrusions consist of mostly tonalites and granodiorite. Late- to post tectonic intrusions consist of granitoids with calc-alkalic- to alkalic affinities, including the Sturgeon Narrows Alkalic Complex (SNAC). The SNAC consists of mainly syenites and is spatially associated with the ABMA (Sanborn-Barrie and Skulski, 2005; Nelson et al. 2021).

Field Observations: Lithofacies and stratigraphic relationships of the Ament Bay Metasedimentary Assemblage

In July 2021, numerous traverses were made within the ABMA to evaluate its sedimentology, structural characteristics, and contact relationships. Three outcrops exposing a contact between ABMA and volcanic rocks were mapped in detail. The following summarizes the new observations.

Lithofacies of Ament Bay Metasedimentary Assemblage

Based on field observations and thin section analysis, three lithofacies have been identified in the ABMA: (i) conglomerate-sandstone, (ii) arkosic wacke and (iii) lithic wacke. Younging directions indicated by scours, cross-bedding, grading (figs. 3,4) suggest the arkosic and lithic wacke overlies conglomeratic units, implying that both the wacke lithofacies represent the final depositional stages of the basin, and conglomerate-sandstone represents the basal unit. This fining-upward stratigraphy is a typical characteristic of collisional basins in the Superior craton (Thurston and Chivers, 1990; Corcoran and Mueller, 2007).

Conglomerate-sandstone lithofacies

The conglomerate-sandstone lithofacies is the most well-exposed in the ABMA. It consists of mostly weakly- to strongly foliated, planar- to massive bedded immature arenites and polymictic conglomerates, which are commonly interbedded with thicknesses of centimetre- to metre scale; however, the proportion of arenites increase up-section. The arenites are fine- to coarse-grained and locally display graded bedding, cross-bedding and scours (fig. 3). The polymictic conglomerates are mostly matrix supported, and consist of granule- to cobble sized subangular- to subrounded clasts. The composition of the matrix is interpreted to be mostly felsic and locally mafic. The clast composition is dominantly felsic volcanic, clastic, and mafic volcanic, with minor iron formation, chert, and gabbro. Granitoid clasts are locally abundant, and are restricted to the outcrop illustrated in figure 5. Two anomalous occurrences of massive, matrix supported conglomerates occur in the Sturgeon Narrows as well as within the central portion of ABMA. The magnetite-rich conglomerate exposure in the Sturgeon Narrows is intruded by a felsic alkalic intrusion (fig. 4b). The latter consists of dominantly mafic volcanic granule- to cobble sized clasts and is intruded by gabbro (fig. 4c).

Arkosic wacke-mudstone lithofacies

The only outcrops of the arkosic wacke-mudstone lithofacies occur on a large island in western Sturgeon Lake. It consists of a strongly foliated, dark grey, thinly bedded wacke-mudstone sequence. Grain sizes range from fine-grained in the west to very fine-grained toward the east. Based on the abundance of feldspar clasts within a muddy matrix observed in thin section, the sandstone in this lithofacies is classified as arkosic wacke.

Lithic wacke lithofacies

This lithofacies is exposed in the northern area of the ABMA. It is moderately foliated and thinly bedded, and is locally interbedded with mudstone/siltstone. It consists of a light grey-greyish green muddy matrix and angular, fine-grained sand- to granule sized clasts which display graded bedding (figs. 4d, 6). Clast counts conducted in thin section show that lithic clasts are dominant, therefore this lithofacies is identified as lithic wacke. Lithic wacke is interpreted to transition laterally (along strike) from the arkosic wacke lithofacies.

Stratigraphic Relationship Between ABMA and Volcanic Units

Four outcrops observed this summer display interbedded sandstones/conglomerates and mafic flows and volcaniclastic rocks of mafic- to intermediate composition, all of which occur proximal to the inferred mapped contact between the CSA and the ABMA defined by Sanborn-Barrie and Skulski (2005). The contacts between the sedimentary and volcanic rocks are gradational- to sharp with steep, concordant bedding parallel to foliation. Interbedded volcaniclastic rocks and conglomerates occur in a shoreline outcrop on a small island in western Sturgeon Lake. The conglomerate in this location is thickly bedded and consists of thin sandy lenses which display graded bedding. The conglomerate consists of a fine- to medium grained sandy matrix which hosts granule- to pebble sized, subangular- to subrounded clasts. The clast composition is mostly felsic and mafic volcanic material with minor banded iron formation (BIF). The volcaniclastic rocks are moderately- to strongly foliated and occur as meter-scale beds which locally display cross-bedding. They are dominantly intermediate to the south and mafic to the north, with lapilli tuff occurring in between (fig. 7a). Another contact was observed on the southeastern shore of Sturgeon Lake, proximal to the contact between the South Sturgeon Assemblage and CSA. In this locality, a meter-thick massive bed of felsic volcanic-rich conglomerate occurs interbedded with pillowed- to massive basalt flows. The conglomerate consists of granule- to cobble sized, subangular- to subrounded, matrix supported clasts. The pillow basalt is weakly foliated south of the contact and well-foliated north of the contact. Another outcrop displaying an interbedded relationship between the volcanic flows and ABMA occurs on Highway 599 (fig. 7b). In this exposure, massive- to pillowed basalt occurs

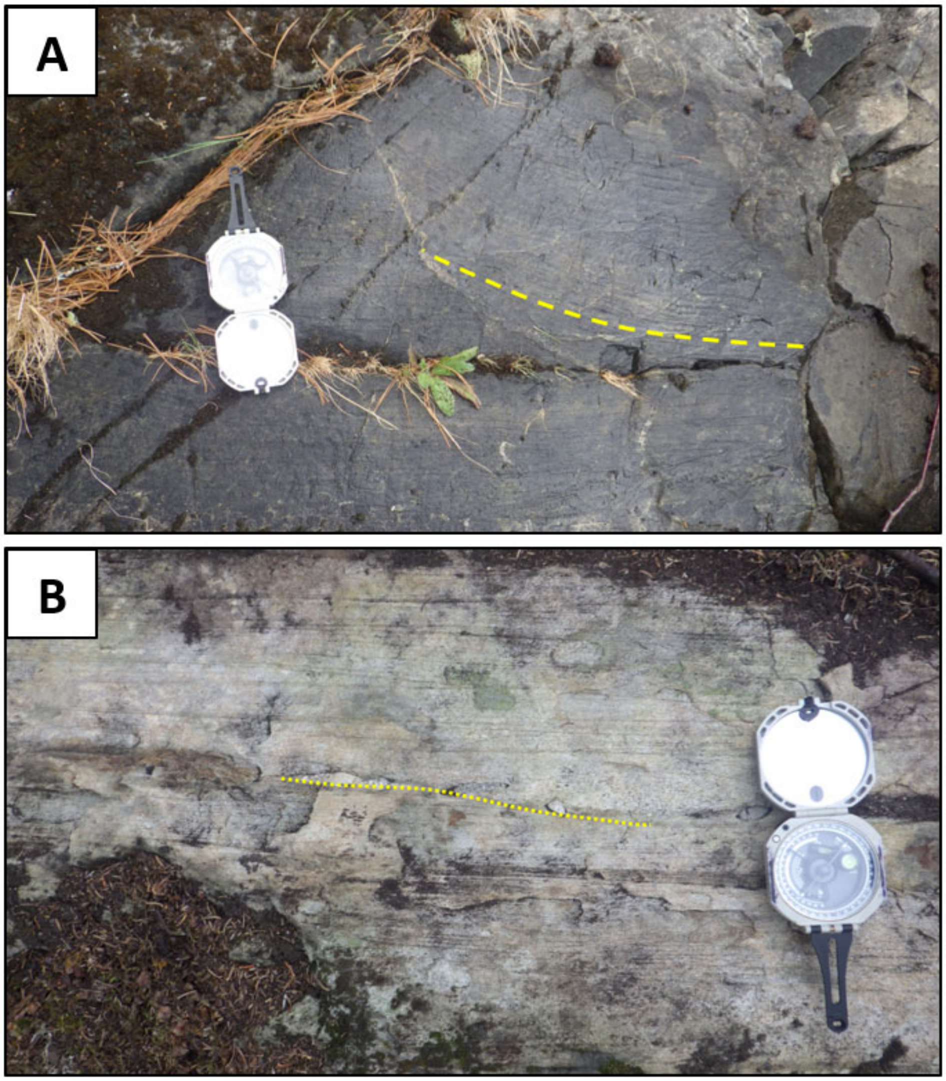

Figure 3. Outcrops from the conglomerate-sandstone lithofacies A) Cross-bedded arkose indicating south- younging direction; UTM 649249E/5533586N B) Scour with granules along its surface in planar cross-stratified arkose indicating north-younging direction; UTM 642976E/5530406N. Both UTM coordinates provided use NAD83 in zone 15.

interbedded with thin, well foliated conglomerate layers. The conglomerate in this locality is matrix supported with granule- to pebble sized subrounded- to subangular clasts which are dominantly felsic volcanic. Mafic- to intermediate flow also occurs in sharp contact with lithic greywacke near the northernmost mapped contact between ABMA and the CSA. Way-up indicators such as pillow structures and grading indicate the contacts are north-younging in the southern region and south-younging in the northern region of ABMA; consistent with the regional syncline model suggested by Sanborn-Barrie and Skulski (2006).

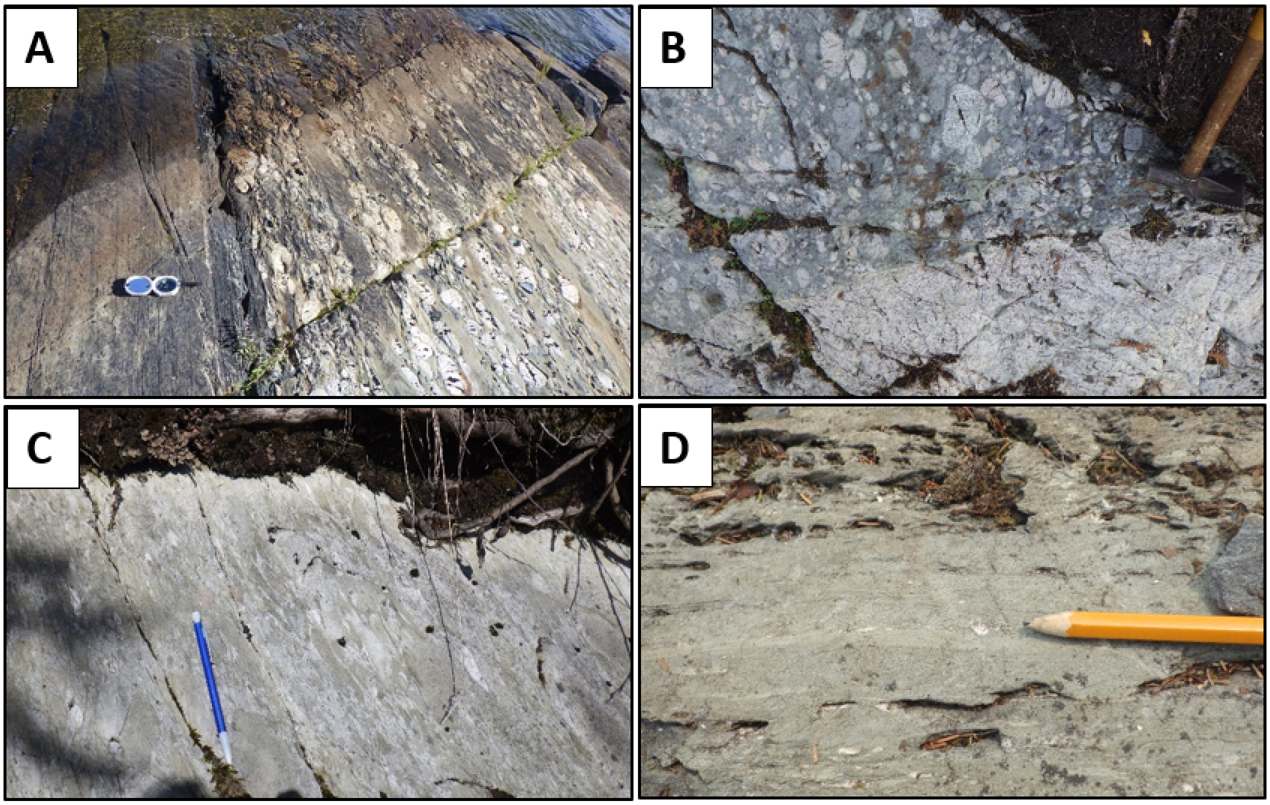

Figure 4. A) Interbedded conglomerate and sandstone overlain by planar cross-stratified arkose; UTM 642976E/5530406N B) Massive, magnetite-rich polymictic conglomerate intruded by felsic alkalic dyke; UTM 656950E/5537092N C) Massive, mafic volcanic-dominated conglomerate; UTM 650501E/5533729N D) Graded bedding in lithic greywacke indicating south-younging direction; UTM 650123E/5533984N. All UTM coordinates provided use NAD83 in zone 15

Evidence for Coeval Relationship between ABMA and Alkalic Complexes

A crucial feature in Timiskaming-type basins in the Abitibi greenstone belt is a coeval relationship with alkalic magmatism. Alkalic rocks in the Abitibi intrude Timiskaming Group sediments and are also incorporated as clasts (Thurston and Chivers, 1990; Corfu et al. 1991; Legault and Hattori, 1994). The SLGB hosts four syenite-dominated alkalic plutons which surround the ABMA, including the SNAC which occurs in closest proximity to the ABMA. The SNAC consists of mostly nepheline syenite and is observed to intrude massive, magnetite-rich conglomerate in the Sturgeon Narrows (fig. 4b). Syenite and trachytic clasts are documented in ABMA conglomerates sampled in 2020, thus implying that the ABMA is coeval with alkalic magmatism, however their source pluton is currently unclear.

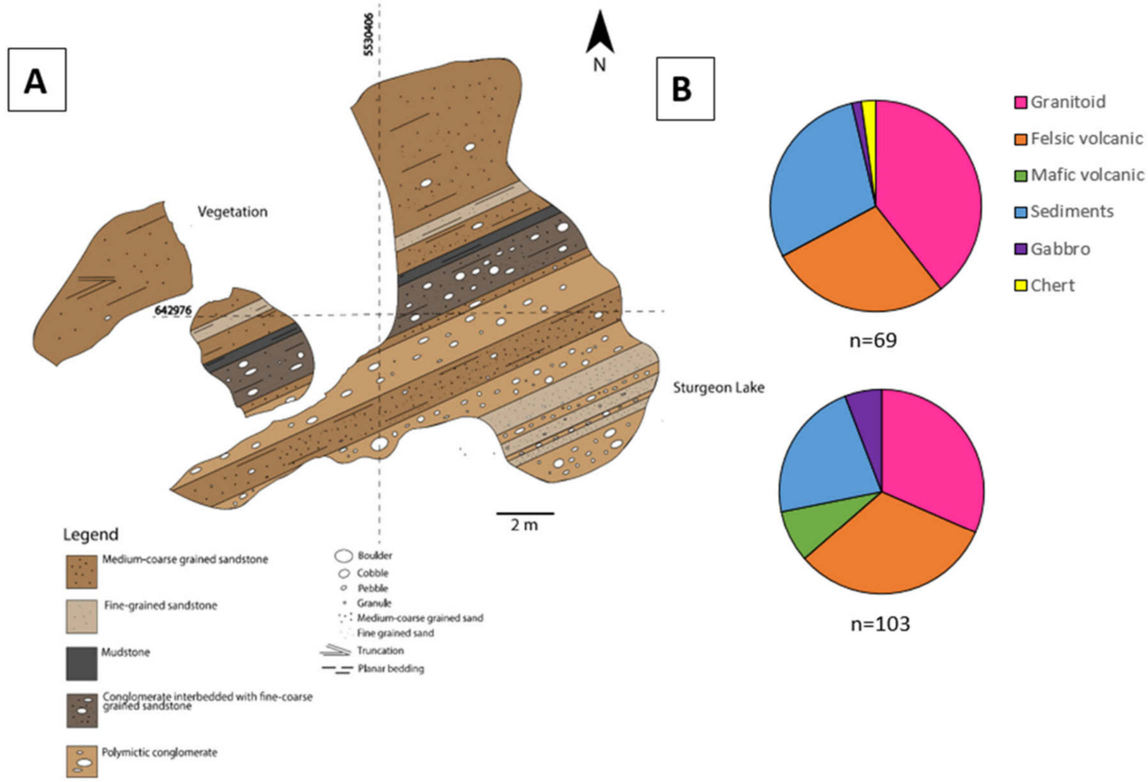

Figure 5. A) Outcrop map from conglomerate-sandstone lithofacies. B) Clast count pie diagrams representing the clast composition proportions from this outcrop. Data collected in 0.5 m x 0.5 m grids.

Future Work

Eighteen samples were collected from the ABMA for U/Pb geochronology (nine sediments and nine clast samples) to determine maximum depositional age and provenance. Petrographic and geochemical analysis will be conducted on the sediments for sandstone classification. Felsic volcanic and plutonic clasts were collected for both whole-rock geochemistry and U/Pb dating. Felsic volcanic clast compositions and ages will be compared to grab samples collected from felsic volcanic assemblages in the SLGB to determine their sources. Three granitoid clasts were collected from the same outcrop where a syenite clast was found in 2020. The conglomerate in this outcrop consists of mostly granitic clasts (fig. 5), therefore their compositions will be studied through whole-rock geochemistry and petrography to determine if syenite is the dominant clast. One granitic clast from this outcrop was collected for U/Pb dating to compare with the ages of surrounding plutons in the SLGB. Trachytic clasts are abundant in ABMA conglomerate samples collected in

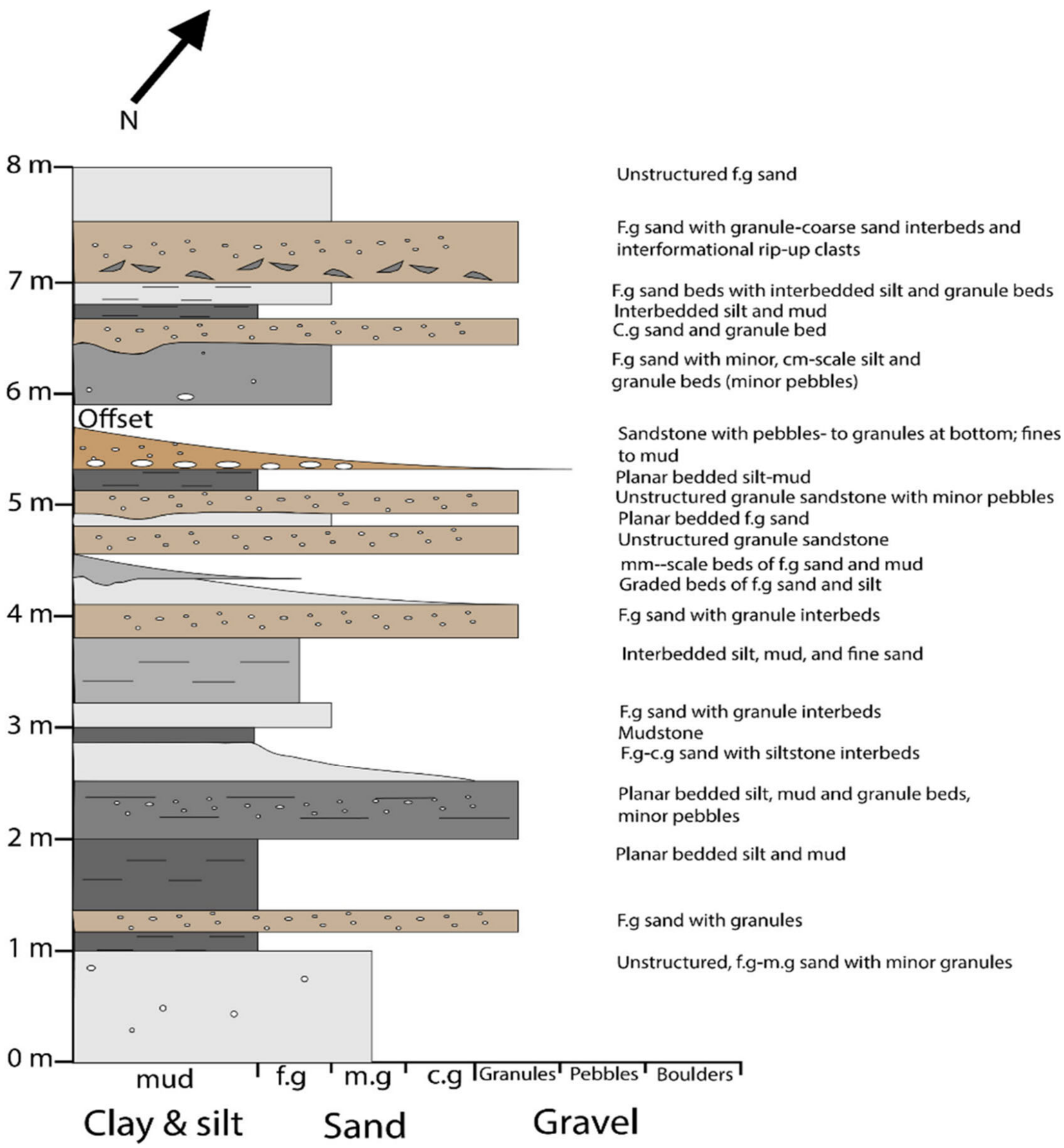

Figure 6. Stratigraphic column representing the lithic greywacke lithofacies; UTM 646340E/5532182N NAD83 Zone 1.

2020, however, they are difficult to distinguish in the field therefore they must be identified through thin section and/or whole-rock geochemistry. One assay sample was obtained from the magnetite-rich conglomerate in the Sturgeon Narrows. This conglomerate is intruded by a felsic dyke belonging to the SNAC (fig. 4b), which is currently interpreted to have introduced skarn- type magnetite mineralization. Metallurgic data will be used to test this hypothesis and evaluate its economic potential. Twelve mafic- to intermediate volcanic samples in contact with ABMA sedimentary rocks were collected for U/Pb dating to determine if they belong to the CSA or represent a volcanic lithofacies within the ABMA. Two intrusive rocks including gabbro and a granitic dyke observed to intrude ABMA were sampled for U/Pb geochronology to constrain the age of the ABMA. Whole-rock data from both clastic and igneous samples will be plotted on a Zr/Sc vs. Th/Sc diagram to evaluate potential sources for the ABMA.

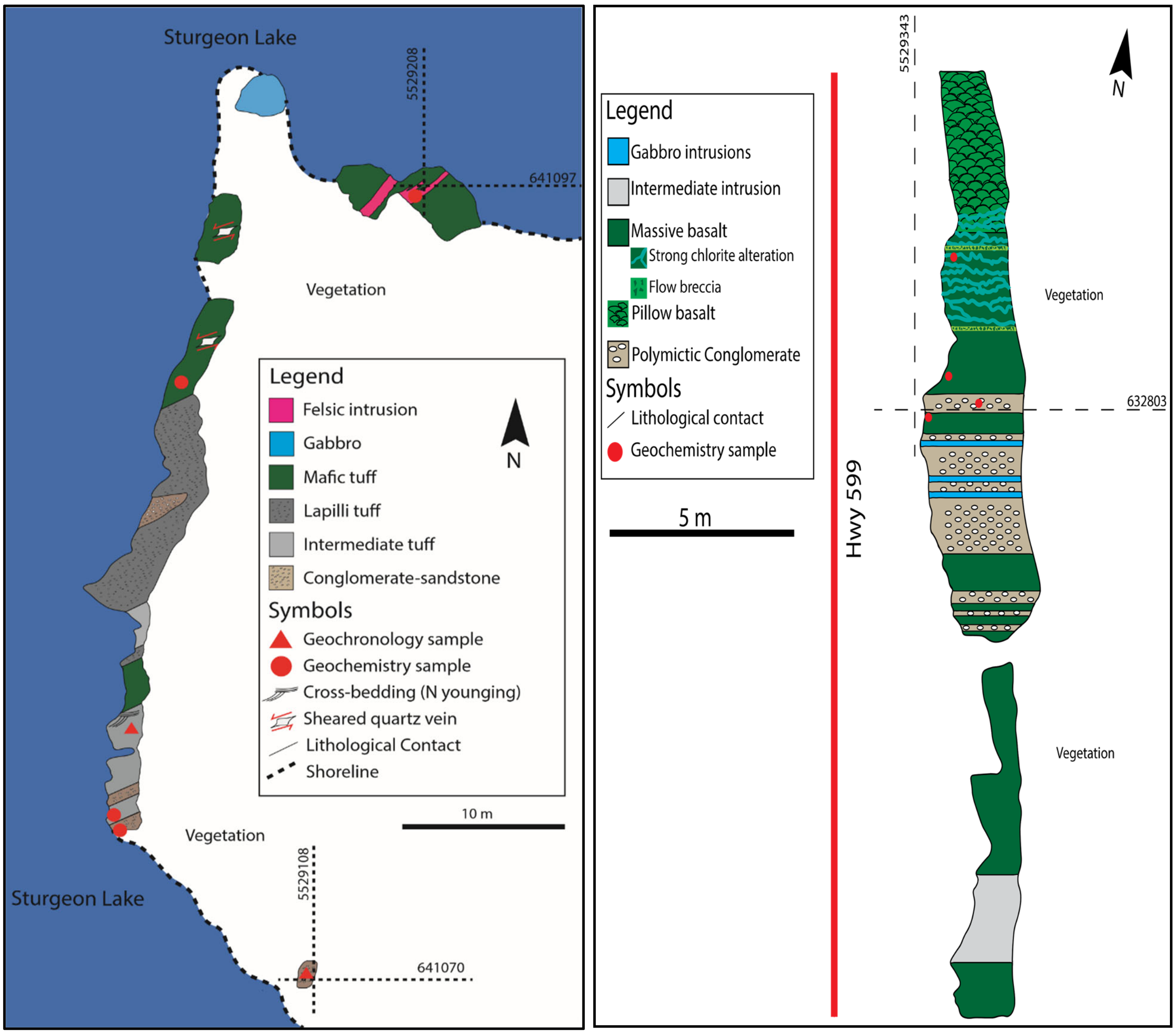

Figure 7. Outcrop maps displaying ABMA and volcanic contacts. A) Outcrop in western Sturgeon Lake exposing volcaniclatic rocks in gradational contact with ABMA sediments B) Roadside outcrop along Highway 599 exposing conglomeratic rocks interbedded with mafic flow

Tentative Origin for the ABMA

Archean late-orogenic successor (Timiskaming-type) basins studied by Mueller and

Corcoran (1998) are characterized by bounding crustal-scale faults and abundant porphyry stock emplacement. Based on fining-upward stratigraphy and fault boundaries, Mueller and Corcoran (1998) suggested these basins are tectonically controlled and developed in a pull-apart regime. The lithofacies that make up these basins include felsic- to mafic volcanic rocks, pyroclastic/volcaniclastic rocks, conglomerate-sandstone, and argillite-sandstone. Comparable lithofacies in the ABMA include conglomerate-sandstone and argillite-sandstone (argillite-sandstone may be represented by greywacke units in ABMA). These lithofacies represent fluvial- to stream-dominated alluvial fan deposits and upper- to lower shoreface deposits, respectively (Mueller and Corcoran, 1998). Successor basins defined by Mueller and Corcoran (1998) consist of a regional-scale basal unconformity; however, the interbedded relationship of mafic- to intermediate volcanic units and terrigeneous clastic rocks occurring near the inferred mapped contact of CSA and ABMA implies a conformable relationship between the two assemblages. Another possibility is that the interbedded mafic volcanic flows and volcaniclastic rocks could be included as ABMA lithofacies. This can be comparable to the Kirkland Basin of the Abitibi greenstone belt (Mueller and Corcoran, 1998; fig. 8). In this basin, reworked volcaniclastic rocks and mafic volcanic flows occurs intercalated with the conglomerate-sandstone lithofacies, similar to the outcrops illustrated in figure 7. However, no porphyry stock is observed to intrude the ABMA (possibly due to lack of exposure). There is no clear unconformity between older volcanic rocks and the ABMA, therefore a final conclusion is dependant on geochronology work this fall 2021.

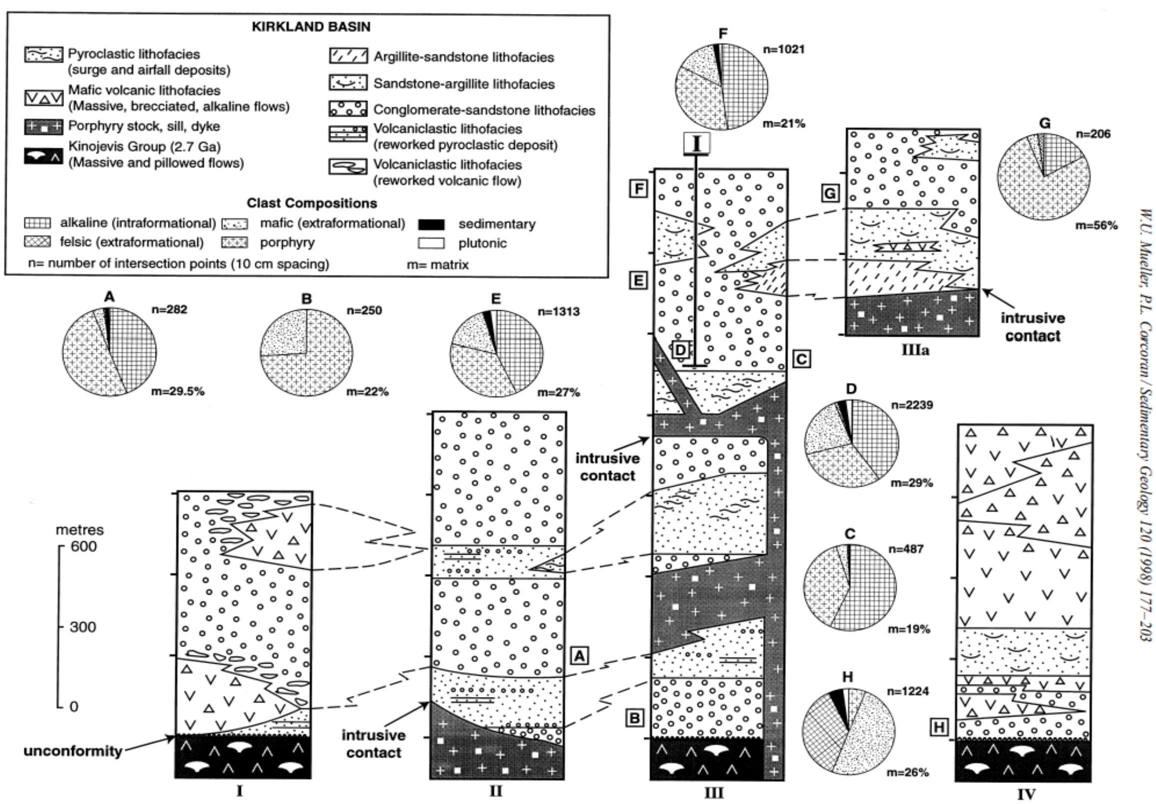

Figure 8. Composite stratigraphy of the Kirkland Basin of the Abitibi greenstone belt with clast composition diagram. From Mueller and Corcoran (1998).

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