APPENDIX 1

Volcanic Stratigraphy

Over the past hundred years, the E-trending successions of deformed volcanic rocks were subdivided into distinct rock units and assemblages, formally named to map and trace units in the different mining camps and across the Quebec-Ontario border (Gunning and Ambrose, 1939, 1940; Hurst, 1939; Wilson, 1941, 1962; Thomson, 1941; Ferguson et al., 1968; Goodwin, 1979; Jensen and Langford, 1985; Daigneault et al., 1990; Ayer et al., 2002a, b, 2005; Thurston et al., 2008; Monecke et al., 2017). In this compilation, a modified version of the chronostratigraphic nomenclature of Ayer et al. (2002a), Thurston et al. (2008), and Monecke et al. (2017) is used to designate larger packages of volcanic and sedimentary rocks that are broadly coeval with similar lithologic attributes and geochemical and geophysical signatures. The nomenclature used here largely borrows on the previously proposed assemblages (Ayer et al., 2002b), but it also takes into account equivalent groups and formations established at district scale (Thurston et al., 2008). Although not immune to inconsistencies (as discussed in Monecke et al., 2017), this approach allows for the correlation of key geologic features at the scale of the belt and also presents the distribution of the gold mineralization in space and time (Figs. 1-3). Seven submarine volcanic assemblages, including Group(s) and Formation(s), between ca. 2795 and 2695 Ma are distinguished. These volcanic assemblages mostly consist of tholeiites and komatiites, locally with coeval calc-alkaline intermediate to felsic volcanic rocks. From oldest to youngest, the assemblages are the Chrissie-Fecteau (2795–2759 Ma), Pacaud/Gemini-Turgeon (2750–2735 Ma), Deloro/Obatogamau-Waconichi (2734–2724 Ma), Stoughton-Roquemaure (2723–2720 Ma), Kidd-Munro/Lanaudière-Lamotte-Vassan (2719–2711 Ma), Tisdale-Val d'Or (2710–2704 Ma), and Blake River (2704–2695 Ma) volcanic assemblages (Figs. 1-3). These volcanic assemblages are disconformably or unconformably overlain by early deep submarine turbidites (Porcupine-Cadillac, and the Chicobi, Taibi, Caopatina, and Stella) by late fluvial-alluvial conglomerates and sandstone intercalated with minor alkalic to shoshonitic volcanic rocks (Timiskaming and Haüy: Cooke and Moorhouse, 1969; Mueller and Donaldson, 1992; Mueller et al., 1994; Mueller and Corcoran, 1998; Wilkinson et al., 1999). The <2700 to 2685 Ma Porcupine-Cadillac-Kewagama and the <2679 to <2669 Ma Timiskaming basins are present in

the southern Abitibi greenstone belt, whereas the Chicobi-Taibi-Caopatina-Stella (<2707–<2685 Ma) and the Haüy (<2692 Ma) basins are present in the northern Abitibi. Although, the range of deposition ages as constrained by the youngest detrital zircon in each sample is large, the Porcupine-Cadillac-Kewagama turbidites were deposited at about 2685 Ma (Davis, 2002), whereas deposition of at least part of the Timiskaming Group in Ontario and Quebec is constrained at, respectively, <2669 ±1 and ~2673 ± 2 Ma (Davis, 2002; Snyder et al., 2004).

Chrissie-Fecteau assemblage (2795–2759 Ma)

The 2795 to 2759 Ma Chrissie/Fecteau assemblage is present south of Chibougamau in the northeastern part of the belt (Fig. 1). It is composed of mafic tholeiitic volcanic rocks (lower member of the Chrissie Formation) and felsic calc-alkaline volcanic rocks (upper member of the Chrissie Formation) that include the oldest rhyolite in the Abitibi at 2791 +4/–3 Ma (David and Dion, 2010). It may also include the <2757 Ma (Mortensen, 1993b) pyroclastics rocks of the Lac-des-Vents Member south of Chibougamau. The coeval 2791.0 ± 1.0 Ma rhyolites of the Fecteau Formation are present south of Chibougamau in the Urban-Barry belt (Fig. 1; Bandyayera et al., 2004).

Pacaud/Gemini-Turgeon assemblage (2750–2735 Ma)

The 2750 to 2735 Ma Pacaud /Gemini-Turgeon assemblage is mainly composed of tholeiitic mafic volcanic rocks with lesser amounts of calc-alkaline, intermediate to felsic volcanic rocks that characterize the Pacaud Group in Ontario and the Gemini-Turgeon Formation in Quebec, plus other less extensive rock sequences of similar age. It also contains the oldest komatiites of the belt (Thurston et al., 2008). It is mainly exposed in the southern Abitibi, especially in the Shining Tree area (Fig. 1), where it has an apparent thickness of 5,000 m (Ayer et al., 2002b). In the Swayze area (Fig. 1), mafic and felsic volcanic and volcaniclastic rocks of the Chester Group have been assigned to the Pacaud/Gemini-Turgeon assemblage (Ayer et al., 2002b; van Breemen et al., 2006; Gemmell and McDonald, 2016). The synvolcanic ca. 2741 to 2739 Ma Chester Intrusive Complex hosts the large Côté gold deposit (Kontak et al., 2013; Katz et al., 2017, Figs.

1, 2). The 2736 ± 1 Ma Gemini-Turgeon Formation rhyolite (Davis et al., 2005) is present in the northern Abitibi, west of Joutel (Fig. 1; Thurston et al., 2008).

Deloro/Obatogamau-Waconichi assemblage (2734–2724 Ma)

The 2734 to 2724 Ma Deloro/Obatogamau-Waconichi assemblage conformably overlies the Pacaud/Gemini-Turgeon assemblage and is up to 5,000 m in thickness (Ayer et al., 2002b). The Deloro Group consists of pillowed calc-alkaline mafic flows (Pyke, 1982) and intermediate to felsic volcanic and volcaniclastic rocks, with some tholeiitic mafic volcanic rocks. Regionally extensive oxide iron formation intercalated with 2724.5 ± 2.1 Ma felsic volcaniclastic successions are present toward the upper part of the Deloro Group (Ayer et al., 2002b; Thurston et al., 2008, Monecke et al., 2017a). In the northern part of the belt (Fig. 1), this assemblage is correlated in age with the tholeiitic basaltic rocks of the Obatogamau Formation at the base, and the 2730 to 2726 Ma felsic rocks of the Waconichi Formation in the upper part (Mortensen, 1993a; McNicoll et al., 2008; Leclerc et al., 2011, 2012). Farther to the west, the volcanogenic massive sulfide (VMS) deposits of the Matagami camp are hosted by 2726 to 2723 Ma tholeiitic intermediate to felsic volcanic rocks correlated with the Deloro Group (Mortensen, 1993a; Ross et al., 2014). West of Matagami, the >2725 Ma mafic-ultramafic flows and intrusion of the Lower Detour Lake Formation, which hosts the Detour gold deposit (Oliver et al., 2012), are correlated with the Deloro Group (Oliver et al., 2012).

Stoughton-Roquemaure assemblage (2723–2720 Ma)

Volcanic rocks of the 2723 to 2720 Ma Stoughton-Roquemaure assemblage show a widespread distribution throughout the belt, forming broad E-W-trending regions of tholeiitic massive and pillowed basalts, komatiitic basalts, and komattites with minor felsic volcanic centers. This short time interval represents the main volcanic succession in the central part of the belt with 100- to 1,000-m-thick basaltic flow units continuous for tens of kilometers (Barrie, 1999a; Ayer et al., 2002b; Mueller and Mortensen, 2002; Thurston et al., 2008). In the Chibougamau area, it corresponds to the extensive mafic volcanic rocks of the Bruneau Formation (former Gilman

Formation: Leclerc et al., 2012). It may also include the volcaniclastic rocks of the <2721 ± 3 Ma Blondeau Formation (Leclerc et al., 2012).

Kidd-Munro/Lanaudière-Lamotte-Vassan assemblage (2719–2711 Ma)

Volcanic rocks of the 2719 to 2711 Ma Kidd-Munro/Lanaudière-Lamotte-Vassan assemblage conformably overlie the Stoughton-Roquemaure and are present throughout the central and southern parts of the belt (Figs. 1, 2; Thurston et al., 2008). In the southern Abitibi, it forms an up to 5,000-m-thick extensive E-trending assemblage that extends for about 500 km from the Kapuskasing structural zone to the west to the contact with the Grenville Province to the east (Thurston et al., 2008; Monecke et al., 2017a). It mostly comprises mafic to intermediate tholeiitic volcanic rocks, subvolcanic intrusions, with subordinate amounts of komatiite flows and local rhyolite (Barrie, 1999a, b; Bleeker, 1999; Ayer et al., 2002a, b; Berger, 2011). To the east, an example of such spinifex-textured komatiite flows is well exposed at Spinifex Ridge (Champagne et al., 2002; Houlé et al., 2017).

Tisdale/Val d'Or assemblage (2710–2704 Ma)

The tholeiitic basalts and rhyolites, komatiites and calc-alkaline, intermediate to felsic volcanic rocks of the 2710 to 2704 Ma Tisdale Group and the Val d'Or Formation crop out from the Kapuskasing structural zone to the Val-d'Or area in the east (Ayer et al., 2002b; Monecke et al., 2017a; Figs. 1, 2). The assemblage is also present in the southwestern Abitibi where it is known as the Larder Lake Group. Basalt, gabbro, and felsic volcanic rocks of the 2707 ± 3 Ma Urban Formation south of Chibougamau in the northeastern part of the belt are also correlative (Fig. 1; Thurston et al., 2008). The largest outcrop area occurs between the Destor-Porcupine and the Larder Lake-Cadillac fault zones, particularly west of Kirkland Lake (including the Swayze greenstone belt), and in the Cadillac and Val-d'Or areas (Fig. 2). Although, recent U-Pb dating indicates that some of the volcanic and volcaniclastic rocks in the Swayze greenstone belt area originally correlated with the Tisdale Group, they have Blake River Group age (Gemmell and Szumylo, 2019). Mafic and ultramafic volcanic rocks with local intercalations of mudstone and iron formation are also present south of the Larder Lake-Cadillac fault zone in the Kirkland Lake

area (Larder Lake Group; Ayer et al., 2002b). In the Timmins area, the Tisdale Group is also present north of the Destor-Porcupine fault zone, where it is more than 2,000 m thick and consists, from base to top, of komatiites and basaltic komatiites, basaltic flows, and minor carbonaceous mudstone and spherulitic basaltic flows, interlayered with carbonaceous intraflow mudstone units (Ferguson et al., 1968; Pyke, 1982; Mason and Melnik, 1986; Bateman et al., 2008; Dubé et al., 2017). Highly strained spinifex-textured komatiites and mafic volcanic rocks of the correlative Piché Group are commonly present within the Larder Lake-Cadillac fault zone (Bedeaux et al., 2017, 2018a; Poulsen, 2017). These highly strained rocks vary in width from a few meters to hundreds of meters and are interpreted as a fault-bounded tectonic slice of the Tisdale-Val d'Or assemblage that has been incorporated within the fault zone (Poulsen, 2017).

Blake River assemblage (2704–2695 Ma)

The Blake River (2704–2695 Ma) is the youngest volcanic assemblage of the Abitibi greenstone belt. The assemblage largely consists of the Blake River Group that straddles the Quebec and Ontario border (Jensen and Langford, 1985). It also includes the Kamiskotia Volcanic Complex northwest of Timmins (Hathway et al., 2015), the Kinojevis Group east of Timmins (Jensen and Langford, 1985), the Skead (Corfu, 1993) and Swayze (van Breemen et al., 2006) Groups in southern Abitibi, and the Louvicourt (Scott et al., 2002) and Villebon (Moorhead et al., 2000) Groups in the Val-d'Or area (Monecke et al., 2017a, and references therein). Rocks of the Blake River assemblage locally conformably overlie the volcanic rocks of the 2710 to 2704 Ma Tisdale/Upper Malartic assemblage but are generally in structural contact with the other assemblages.

The Blake River assemblage consists of submarine volcanic and volcaniclastic sequences, cut by numerous synvolcanic and syntectonic intrusions (e.g., Dimroth et al., 1978; Dimroth and Rocheleau, 1979; Péloquin et al., 1990; Ross et al., 2011a, b). It is bounded by the Destor-Porcupine fault zone to the north, and the Larder Lake-Cadillac fault zone to the south (Fig. 2). Recent mapping and U-Pb geochronology (e.g., Mueller et al., 2012; McNicoll et al., 2014) provided significant evidence for a complex volcanic architecture consisting of structural blocks comprising homoclinal panels, complexly folded assemblages, and faulted blocks (Monecke et al., 2017b). The volcanic rocks are predominantly bimodal in composition (Sterckx,

2018, and references therein) with abundant basalt, basaltic andesite and andesite, and numerous felsic (rhyodacitic to rhyolitic) centers of variable size. The Blake River assemblage contains almost half of the cumulative VMS tonnage of the Abitibi greenstone belt with 31 VMS deposits, including 20 past or current producers (Mercier-Langevin et al., 2011a). Importantly, the Bake River Group is characterized by a unique concentration of large (>15 Mt), gold-rich VMS (>3.5 g/t Au, or Au/base metals ratio >1) deposits such as Horne (Barrett et al., 1991), Horne 5 (Krushnisky, 2018), Quemont (Cattalini et al., 1993), LaRonde Penna (Mercier-Langevin et al., 2017a), and Bousquet 2-Dumagami (Tourigny et al., 1993; Dubé et al., 2014), which combined, account for approximately 11% (~1,000 t Au, ~33 Moz) of the gold budget of the Abitibi belt.

Fig. A1. A. Residual total magnetic field of the Abitibi greenstone belt, major fault zones, and distribution and styles of gold deposits. The large-scale geologic contacts shown in Dubé and Mercier-Langevin (2020, fig. 1) are white. B. First vertical derivative of the magnetic field of the Abitibi greenstone belt, main fault zones, and distribution and styles of gold deposits. The dense N-S-trending lineaments in the western part of the map are mainly dikes of the post-Archean Matachewan swarm. Modified from Miles et al. (2000), D'Amours and St-Hilaire (2010), and Keating et al. (2010). PI = Pipestone fault.

Fig. A2. Comparison of Archean granitoids from Abitibi greenstone belt base in Laurent et al. (2014) diagram. A. Synvolcanic and pre-Timiskaming (postvolcanic) intrusions. B. Early- to syn-Timiskaming (and –Haüy) intrusions and post-Timiskaming intrusions and. C. Evolution of intrusive rocks through time at the scale of the Abitibi greenstone belt. Data are from Beakhouse (2011), Bigot and Jébrak (2015), Bourne and Danis, 1987), Campbell (2014), Dubé (2018), Fayol and Jébrak (2017), Feng and Kerrich, (1992b), Galley and Lafrance (2014), Ispolatov et al. (2008), Katz et al. (2017), Kitney et al. (2011), Kontak and Dubé (unpub.), Laurent et al. (2014), Leclerc et al. (2015), Martin (2012), Martin et al. (2012), McDonald et al. (2005), Prud'homme (1990), Roussy (2003), Stern et al. (1989), and Geological Survey of Canada data (unpub. data). Abbreviations: GMG = garnet-muscovite granite, Plag-Hb = plagioclase-hornblende, Qtz = quartz, Fsp = feldspar, TTG = tonalite, granodiorite, and trondhjemite.

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