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GEOLOGICAL SURVEY OF CANADA — COMMISSION GÉOLOGIQUE DU CANADA

DESCRIPTIVE NOTES

The South Sturgeon Lake area consists of a northward younging homocline of Archean volcanic and sedimentary strata, which contain five past-producing volcanogenic massive sulphide deposits. Combined, the Mattabi, F-Group, Sturgeon Lake, Lyon Lake and Creek Zone orebodies produced nearly 18.4 million tons of ore grading 8.5% Zn, 1.06% Cu, 0.91% Pb, and 3.73 ounces/ton Ag between 1971 and 1991. The purpose of this project is to provide documentation of the physical volcanology, hydrothermal alteration, and structural geology of this important mining camp in an effort to develop effective and efficient exploration criteria for similar types of ore deposits in similar settings. Volcanic strata in the region comprise three main stratigraphic elements. The lowermost sequence, displayed on this map, consists of volcanic and related clastic strata, the ore deposits, as well as an overlying thick succession of mafic flows and felsic pyroclastic rocks, and is 2735.5 +/- 1.5Ma (Davis et al., 1985). The overlying sequence consists of mafic and felsic volcanic rocks, with a U/Pb (zircon) age of 2717.9 +2.7/-1.5 Ma. These volcanic strata are overlain by the third principal stratigraphic element, consisting of conglomerate, wacke, shale and iron formation.

The strata have been affected by several deformational events. Synvolcanic and sub-concordant post-volcanic "thrust" faults (see below) were deformed by at least two subsequent folding events. The most prominent fold event imparted a prominent steep dip with an east-west hinge; the latter was then broadly warped about a N-S hinge. Later faults (also described below) locally offset the strata.

The strata of the lowermost sequence consist of twelve "successions". Each is a well-defined unit of volcanic and/or sedimentary strata. Each succession is defined on the basis of laterally consistent strata that are defined by similar volcanic textures, consistency of volcanic process, and composition. The upper and lower boundaries of each succession are generally defined by a major change in lithology or volcanology. Successions may be terminated laterally by caldera paleo-boundaries.

The Darkwater Lake Succession forms the base of the stratigraphic sequence in the South Sturgeon Lake area. These pre-caldera rocks comprise amygdaloidal to massive basalt flows (Unit 1a) which commonly exhibit brecciated and scoriaceous tops; pillow lava and hyaloclastite are rare, identified only in the southeastern part of the study area. Overall, these rocks were deposited in a dominantly subaerial environment. Several units of scoria cone and tuff cone deposits, along with locally well bedded epiclastic rocks (Unit 1b) represent part of a field of small, monogenetic volcanoes on the upper flanks of a major shield edifice. The scoria cone/tuff cone deposits are subaerial to shallow-water subaqueous deposits resulting from magmatic and phreatomagmatic eruptions. Flow banded to massive rhyolite lava flows and lobe lavas (Unit 1c), formed local, discontinuous, volumetrically minor units within the basaltic lava succession east of Jackpot Lake.

The Jackpot Lake Succession overlies the pre-caldera rocks and comprises subaerial to shallow subaqueous rhyolite lava flows (Unit 2a) and aphyric pyroclastic flow deposits (Unit 2b). This succession represents the initial stages of caldera development. Pyroclastic flow deposits (Unit 2b) are aphyric to quartz-phyric (<1 mm), massive to well bedded and locally pumice-rich; minor amounts of interflow debris flow/clastic sedimentary deposits are interlayered with the pyroclastic deposits indicating that eruptions were episodic.

The High Level Lake Succession comprises caldera-collapse associated coarse heterolithic mesobreccia and megabreccia deposits(Unit 3a) that are interlayered with, and grade upward into, bedded quartz-phyric pyroclastic flow and ash tuffdeposits (Unit 3b). Calderas generally represent the collapse of a central volcanic edifice along a series of circular faults. Typically they are identified by diachronous breccia wedges and caldera fill by pyroclastic flows or sediments. The deposits of the High Level Lake Succession typify caldera collapse material, andthis succession marks the transition from a dominantly subaerial environment to a subaqueous environment. The meso- and megabreccia deposits (Unit 3a) have a strike length of at least 22 km. They exhibit rapid changes in thickness from 80 to more than 900 meters. These deposits are composed of block- and lapilli-sized clasts of mafic and felsic volcanic rocks which are texturally, mineralogically, and chemically similar to the underlying Darkwater Lake and Jackpot Lake rocks. Locally, blocks of scoria cone/tuff cone deposits of the Darkwater Lake Succession (Unit 1b) up to 1 km in length and 300 m thick have slid en-masse into the caldera and now form a major component of the various meso- and megabreccia units. The uppermost 5-50 m of the meso- and megabreccia deposits contain sparse quartz phenocrysts and lapilli-sized pumice, which indicate simultaneous deposition and mixing with the overlying quartz-phyric (< 1 mm) High Level Lake Succession pyroclastic flow deposits (Unit 3b). These pyroclastic deposits host the F-Group volcanogenic massive sulphide orebody (380,000 tons grading 9.51% Zn, 0.64% Cu, 0.58% Pb, and 1.92 ounces/ton Ag).

The Bell River Succession comprises intracaldera subaerial- to shallow-subaqueous dacite-rhyolite lava flows, pyroclastic flow deposits, and clastic sedimentary rocks. The lava flows (Unit 4a) are massive, aphyric, and locally spherulitic and/or flow banded and are believed to represent the initial dome complex associated with the caldera. These lava flows are immediately overlain by several units of massive, quartz-crystal poor pumice-rich dacite pyroclastic flow deposits (Unit 4b), which are locally interlayered with a clastic sedimentary rocks and debris flow deposits (Unit 4c). The pyroclastic flow and sedimentary deposits are not observed west of the synvolcanic Darkwater fault, that may represent one side of a topographic depression (local caldera?) which hosts the ore lenses of the Mattabi volcanogenic massive sulphide deposit.

The Tailings Lake Succession comprises up to 400 m of intracaldera, subaqueous debris flow deposits and bedded epiclastic rocks, which are locally separated by dacite-andesite lava flows and dacite ash tuff deposits. Like the Bell River Succession, these rocks are not present west of the Darkwater fault. The debris flow deposits (Unit 5a) are composed of massive non-graded basal units, overlain by well-bedded, locally graded sedimentary material. The percentage of clasts in the debris flows increases westward toward the Darkwater fault and down-dip in deep drill holes, indicating closer proximity to the basin-bounding faults. The lava flows (Unit 5c) are locally feldspar-phyric and vary from massive to amygdaloidal and brecciated. The ash tuff deposits (Unit 5b) are aphyric and fine-grained and host the Mattabi "E" ore lens.

The Mattabi Succession represents the most voluminous eruptive event within the caldera, forming subaqueous pyroclastic deposits that can be traced along strike for more than 20 km and locally exceed 1200 m in thickness. Based on flow morphology and composition, the Mattabi Succession is divided into two distinct units: a) a lower unit (Unit 6a) comprising bedded basal quartz-phyric (up to 2 mm), pumice-rich pyroclastic flow deposits overlain by well-bedded, locally quartz-phyric rhyolite ash deposits; and b) an upper unit (Unit 6b) composed of massive to poorly bedded, aphyric to quartz-shard bearing fine-grained rhyolite ash deposits. The bulk of the Mattabi orebody (12.55 million tons grading 8.28% Zn, 0.74% Cu, 0.85% Pb, and 3.31 ounces/ton Ag) is hosted in this succession. The Mattabi "B", "C", and "D" ore lenses are situated in the lower unit at breaks between quartz-rich beds in the hanging wall, and ash beds in the footwall. The upper unit contains no known massive sulphide mineralization. Both units in the Mattabi Succession contain only pyroclastic units, and were probably deposited in a relatively shallow subaqueous environment.

A sequence of massive to bedded quartz ± plagioclase-phyric rhyodacite-rhyolite subaqueous pyroclastic flow /ash tuff deposits and associated sedimentary rocks, the Lower L Succession, immediately overlies the Mattabi Succession across the entire width of the caldera complex. Massive to bedded, locally graded pyroclastic flow deposits which contain <1-4mm diameter quartz ± plagioclase phenocrysts are interbedded with massive to finely-bedded, aphyric to quartz ± plagioclase-phyric ash tuff deposits (Unit 7a). Several beds of clastic sedimentary rocks with local chemical sedimentary horizons (Unit 7b) are interlayered with, and locally overlie, the pyroclastic deposits. No known economic massive sulphide mineralization is present within this succession.

The Middle L Succession comprises beds of massive to bedded, aphyric, quartz-phyric (<1-4mm), and locally quartz + potassium feldspar-phyric subaqueous rhyolite pyroclastic flows and ash tuff (Unit 8a), and volcaniclastic breccia and associated well bedded heterolithic debris flows and clastic sedimentary rocks (Unit 8b), up to 150m thick. The pyroclastic deposits of the Middle L Succession can be traced across the entire width of the caldera complex and are the host rocks for the Mattabi "A" and possibly the orebody at the Sturgeon Lake Mine (2.28 million tons grading 9.17% Zn, 2.55% Cu, 1.21% Pb, and 3.31 ounces/ton Ag), as well as several laterally equivalent sub-economic massive sulphide occurrences in Area 15, Area 17 and the F-Group claims. Although the Sturgeon Lake Mine occurs in a high strain zone that has been affected by an early "thrust"-type fault, the presence of an alteration zone immediately beneath the deposit that extends several hundred meters into the footwall suggests that this orebody formed in its current stratigraphic position. Units of monolithic to heterolithic breccia containing an abundance of fine-grained, locally spherulitic quartz ± potassium-feldspar lava fragments and accessory fragments, texturally and compositionally very similar to the Beidelman Bay trondhjemite, may represent the proximal deposits from violent vent-clearing subaqueous eruptions.

The Upper L Succession overlies the Middle L Succession and comprises a complex stratigraphic sequence of pyroclastic flow and ash tuff deposits, andesite and dacite lava flows, and volcaniclastic sedimentary strata. The Upper L Succession (Unit 9a) represents the final products of explosive volcanism within the caldera complex. These rocks are composed of massive to bedded, aphyric to plagioclase ± quartz-phyric (<1-4mm) subaqueous pyroclastic flow deposits and ash tuffs. In Area 17, these pyroclastic rocks host a 2 m-thick lens of sub-economic massive sulphide mineralization. Two distinct sequences of subaqueous lava flows are present within the Upper L Succession. The Bell River Lake Sequence comprises massive to amygdaloidal, commonly flow brecciated aphyric to plagioclase-phyric andesitic to dacitic lava flows (Unit 11a) and plagioclase ± quartz-phyric dacitic to rhyodacitic lava flows and flow breccias (Unit 11b), whereas the No Name Lake Sequence is composed of amygdaloidal to massive basaltic to andesitic lava flows, sheet lava, pillow lava, and hyaloclastite deposits (Unit 10a). Both the pyroclastic rocks and the lava flows are interlayered with massive to well-bedded, locally normally graded volcaniclastic sedimentary rocks and debris flow deposits (Unit 9b). The Upper L Succession marks the transition from dominantly explosive volcanism to passive, relatively quiescent volcanic activity within the caldera complex. The morphology of the lava flows suggests that these rocks were formed in a shallow subaqueous environment.

The Lyon Creek Succession comprises subaqueous feldspar-phyric dacite lava flows and domes and associated dome-derived volcaniclastic and chemical sedimentary rocks. The dacite lava flows (Unit 12a) are characterized by the presence of 1-6 mm diameter tabular plagioclase phenocrysts. In Areas 17 and 23, these lava flows make up a lava dome complex that is over 500 m in thickness and up to 3km long. This dome complex occurs close to a caldera margin and is believed to represent the last felsic eruptive product associated with formation of the caldera. Overlying the dome are beds of dome-derived clastic sedimentary deposits (Unit 12b) comprised of arkosic greywacke, massive to well-bedded ash-rich clastic sediments, and matrix-supported lava dome breccia deposits. These clastic sediments are interlayered with, and are locally overlain by, chemical sediments, including graphite-rich greywacke and mudstone deposits (Unit 12d), as well as silica-, carbonate-, oxide-, and/or sulphide-facies iron formations (Unit 12c). These chemical sedimentary strata represent sedimentation in a relatively low-energy environment, and low temperature hydrothermal activity in basins that formed within and adjacent to the growing domes and caldera wall. The Lyon Creek Succession strata represent the uppermost units that are clearly associated with the Sturgeon Lake Caldera Complex.

The Lyon Lake Succession comprises amygdaloidal to massive basalt-andesite to andesite lava flows (Unit 13a) and associated interflow matrix-supported heterolithic debris flow deposits and clastic sedimentary rocks (Unit 13b). The base of the Lyon Lake Succession is characterized by a well-foliated high strain zone up to 100 m thick, which is believed to represent a thrust (?) fault. The Lyon Lake Andesite Succession is chemically distinct from the No Name Lake Sequence within the Upper L Succession, and its relationship to the Sturgeon Lake Caldera Complex is not well understood.

The Swamp Lake Succession is comprised of up to 900 metres of dacite to rhyolite lava flows, pyroclastic flow deposits, and interflow sedimentary rocks. The lava flows (Unit 14a) are massive to amygdaloidal, quartz ± potassium feldspar-phyric, and locally spherulitic. The pyroclastic flow deposits (Unit 14b) typically comprise ash-rich tuffs which grade downward into crystal- and/or pumice-rich pyroclastic flow deposits. The sedimentary strata (Unit 14c) comprise greywacke and heterolithic debris flow deposits. The Swamp Lake Succession immediately overlies the Lyon Lake Succession in the northeastern part of the study area. The contact between these two successions is variable and marked by breccia, quartz veins, extremely fine-grained well-foliated rocks and locally an abundance of dikes. Based on these relationships, the contacts between the Swamp Lake Succession and the Lyon Lake Succession is believed to be structural and may represent a high strain zone similar to the contact between andesite of the Lyon Lake Succession and strata to the south. The age relationship between the Swamp Lake Succession and strata associated with the caldera complex is not well understood.

The stratigraphic positions of the Lyon Lake and Creek Zone orebodies (combined 3.17 million tons grading 8.67% Zn, 1.26% Cu, 0.99% Pb, and 4.50 ounces/ton Ag) have been debated since their discovery. These deposits are associated with, and locally hosted by, quartz-phyric pyroclastic rocks (which are petrographically and chemically similar to the Middle L Succession deposits that host the Sturgeon Lake orebody) and coarse heterolithic breccia. These rocks are in fault contact with the overlying Lyon Lake strata. This post-volcanic "thrust" fault is sub-concordant, but clearly truncates the Lyon Lake orebody at a low angle. The fault and immediately adjacent strata are folded into local, asymmetric "flat zones", along which the orebodies are locally thickened (Koopman, 1993). Early work in the area suggested that these orebodies formed in place in a distal environment on the same horizon as the Sturgeon Lake Mine. This is not possible, however, as it would require the Middle L Succession to simultaneously occur above and below the Lyon Creek Succession. Additionally, these orebodies lack extensive footwall alteration zones that are characteristic of the other ore deposits in the camp. Detailed mapping and core logging in the vicinities of these deposits indicate the presence of a high-strain zone that is probably another early "thrust"-type fault. Based on this evidence, it is now believed that the Lyon Lake and Creek Zone mines comprise fault panels which have tectonically migrated from the vicinity of the Sturgeon Lake mine into their present positions.

Several Intra-Caldera Intrusive Rocks have been identified and include: a) the Beidelman Bay Complex (Unit A), a trondhjemite complex that petrochemical and geochronological data indicate was the subvolcanic intrusion associated with the Sturgeon Lake Caldera Complex; b) massive to amygdaloidal rhyolite (Unit B) which occurs as feeder dikes to the Bell River Succession rhyolite lava flows; c) coarse-grained massive feldspar-phyric diorite (Unit C) which occurs as feeder dikes to the Lyon Creek Succession lava flows and lava domes; and d) a fine-grained massive to amygdaloidal diorite with interstitial quartz plates (Unit D) which dilates the stratigraphy across the entire caldera complex and may have been a subvolcanic sill complex for the No Name Lake Sequence lava flows.

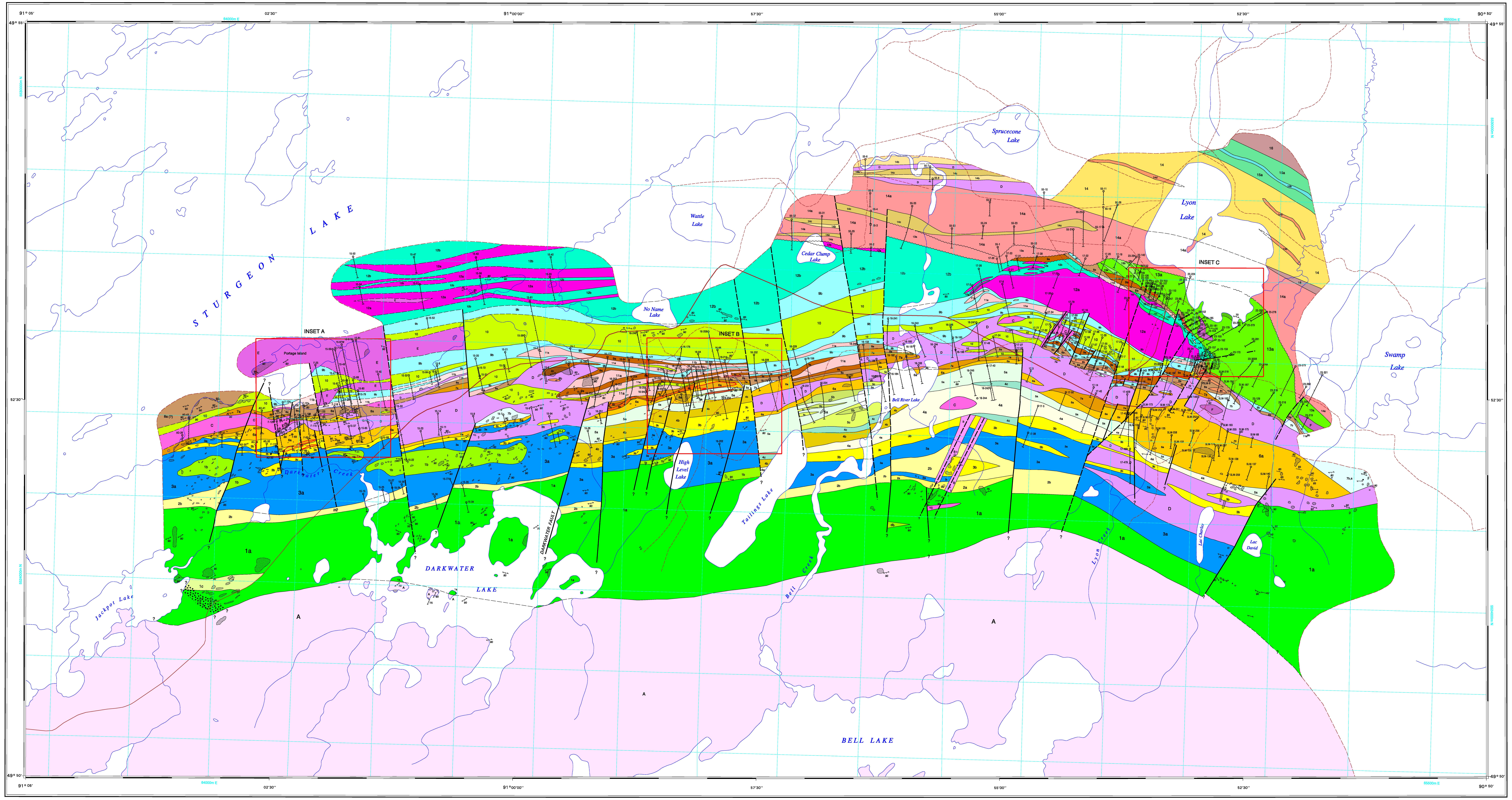
Several Post-Caldera Intrusive Rocks have also been identified and include; a) fine-grained, massive, locally feldspar-phyric diorite (Unit E); and b) coarse-grained amphibole-rich diorite (Unit F). Locally, relatively thin (<1-13m) "lamprophyre" dikes may be present within high-strain areas and post-caldera fault zones.

Three distinctive types of faults have been recognized in the Sturgeon Lake Area: a) synvolcanic faults; b) post-volcanic high-angle faults; and c) post-volcanic "thrust" (?) faults. Synvolcanic faults are recognized using the following criteria: a) apparent offset of a layered unit, with subsequent units not offset; b) abrupt thickening or thinning of a pyroclastic or sedimentary unit; c) more intense hydrothermal alteration and/or abrupt change in alteration type; and d) the presence of apophyses or dikes associated with synvolcanic intrusions. Post-volcanic high angle faults have the following characteristics: a) offset of all stratigraphic units; b) abundance of brittle fracturing and/or lost core; and c) abundance of quartz ± carbonate ± tourmaline veins infilling fractures. Post-volcanic thrust (?) faults can be recognized using a combination of the following criteria: a) intense shearing of adjacent units; b) displacement of older stratigraphic units into positions up-section from younger stratigraphic units; c) presence of "lamprophyre" and/or massive diorite dikes; and d) locally, the presence of graphite-rich breccia zones containing angular quartz-rich fragments.

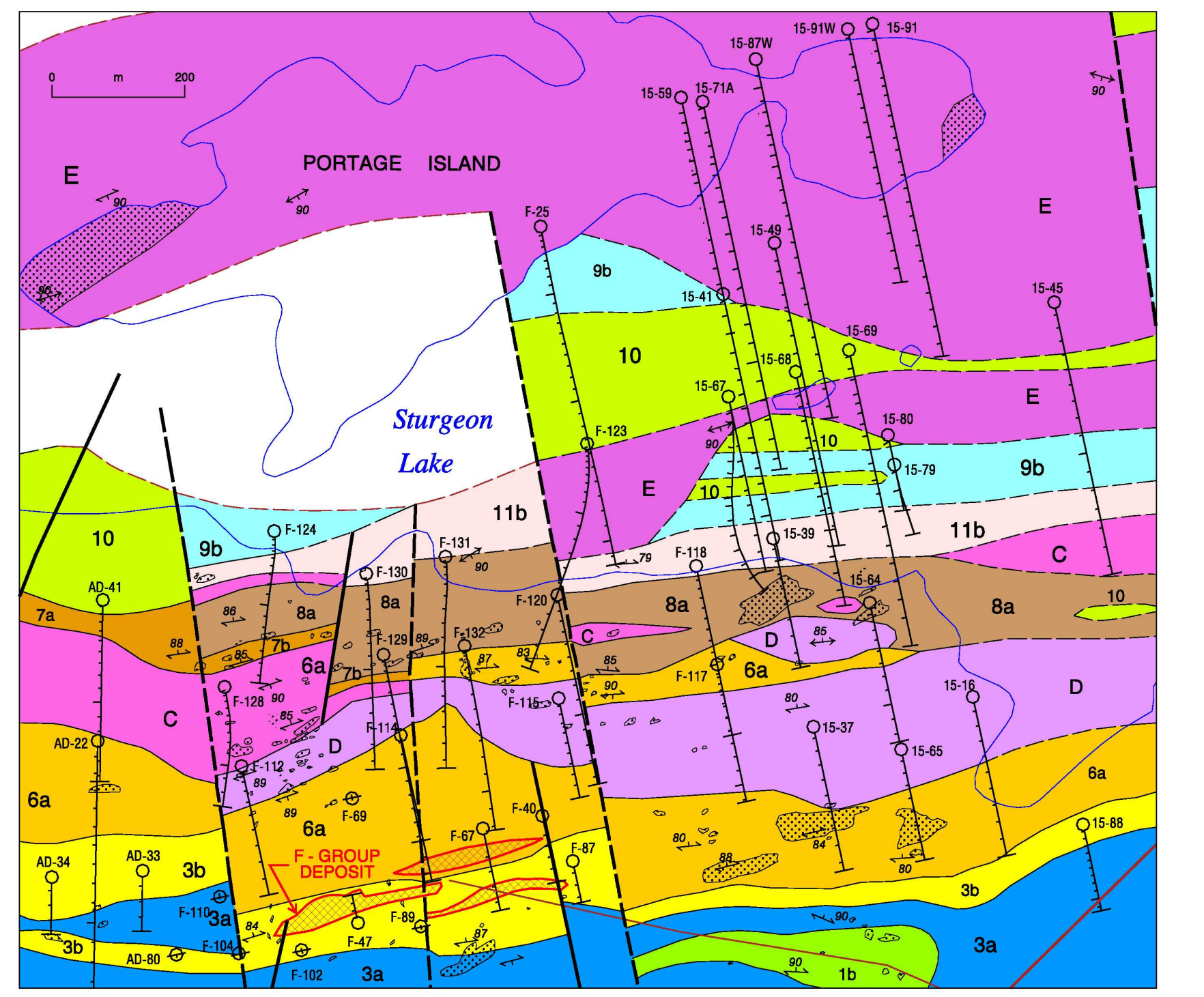
REFERENCES

Davis, D., Krogh, T.E., Hinzer, J., and Nakamura, E.
1985: Zircon dating of polycyclic volcanism at Sturgeon Lake, and implications for base metal mineralization, Economic Geology, vol. 80, p 1942-1952.

Koopman, E. R.
1993: Stratigraphy, structural geology and structural controls of ore distribution of the Lyon Lake massive sulphide deposit, Sturgeon Lake, Ontario, Unpub. M.Sc thesis, Carleton University, 170p.



INSET A



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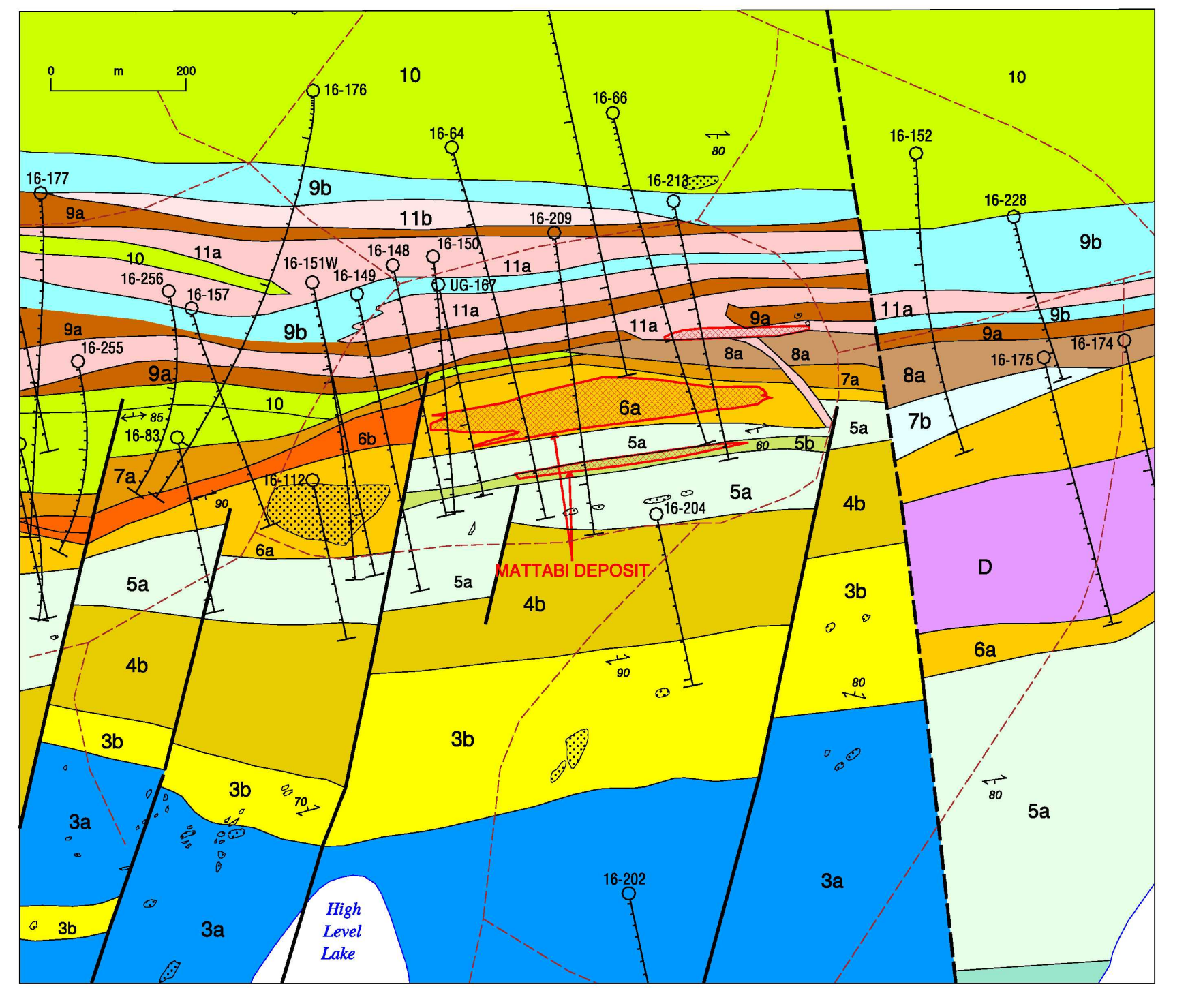

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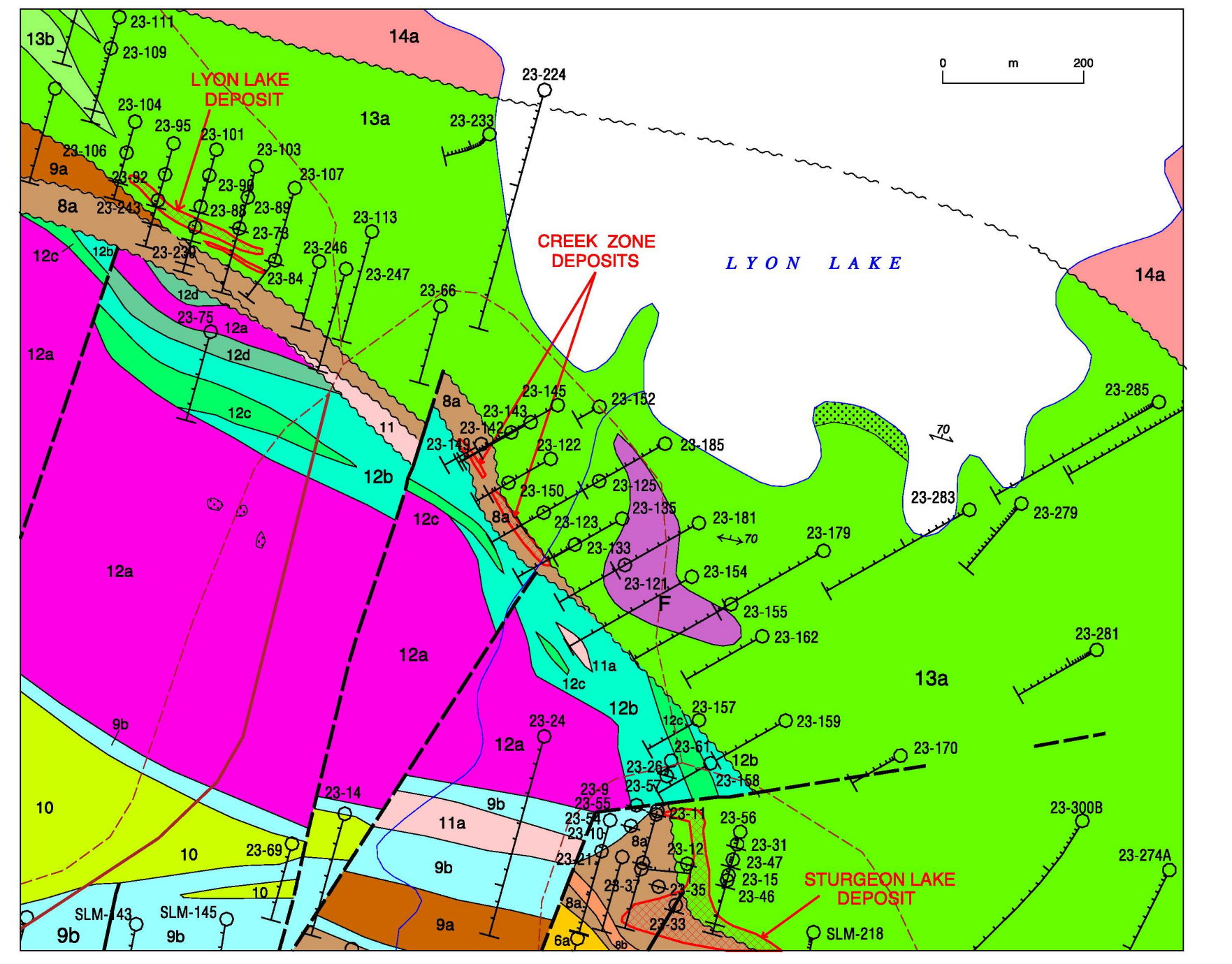

Geology by R.L. Morton, G. Hudak, and J.M. Franklin

Digital cartography by Geoscience Information Division

Any revisions or additional geological information known to the user would be welcomed by the Geological Survey of Canada

Mean magnetic declination 1999, 1°1′W, increasing 4.4′ annually. Readings vary from 1°8′W in the SE corner to 0°54′W in the NW corner of the map

OPEN FILE 3642

GEOLOGY

SOUTH STURGEON LAKE AREA

ONTARIO

Scale 1:15 000 - Échelle 1/15 000

Metres 250 0 250 500 750 1000 1250 1500 Mètres

Universal Transverse Mercator Projection — Projection transverse universelle de Mercator

NODA • EDNO
CANADA ONTARIO
Northern Ontario Development Agreement
Entente de développement du nord de l'Ontario
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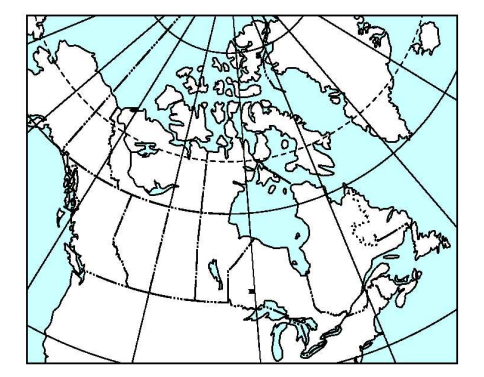
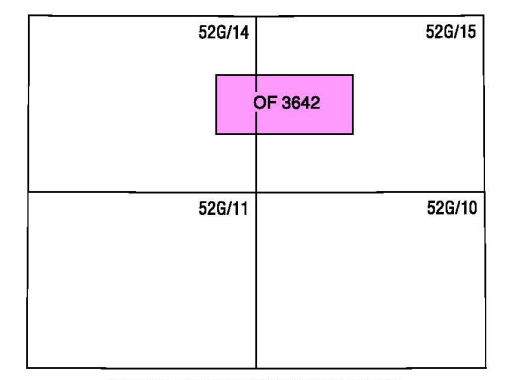

LOCATION MAP



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OTTAWA
08/1999

LEGEND

	INTRUSIVE ROCKS
F	*Amphibole-rich diorite*
E	*Massive diorite*
D	*Quartz-plate diorite / gabbro*
C	*Feldspar-phyric diorite*
B	*Sperulitic rhyolite dikes*
A	*Biedelman Bay trondhjemite*
	SPRUCECONE LAKE SUCCESSION
16	*Ash flow tuff and ash fall deposits*
15a	*Sedimentary rocks, debris flow deposits, and ash deposits*
15b	*Iron formation*
	SWAMP LAKE SUCCESSION
14	*Undifferentiated felsic lava flows, pyroclastic flow deposits and sediments*
14a	*Rhyolite-dacite lava flows*
14b	*Pyroclastic flow deposits*
14c	*Sedimentary rocks*
14d	*Iron formation*
	LYON LAKE SUCCESSION
13a	*Andesite lava flows*
13b	*Clastic sedimentary rocks and debris flow deposits*
	LYON CREEK SUCCESSION
12a	*Dacite lava dome and lava flows*
12b	*Dome-associated clastic sedimentary rocks*
12c	*Iron formation ± chert*
12d	*Graphitic sedimentary rocks*
	UPPER "L" SUCCESSION *BELL RIVER LAKE SERIES*
11a	*Dacite lava flows*
11b	*Quartz + feldspar-phyric dacite- rhyodacite lava flows*
	NO NAME LAKE SUCCESSION
10	*Andesite lava flows,flow breccias, and hyaloclastite*
	UPPER "L" SUCCESSION
9a	*PYROCLASTIC SERIES* *Pyroclastic flow deposits*
9b	*SEDIMENTARY SERIES* *Volcaniclastic sedimentary rocks*
	MIDDLE "L" SUCCESSION
8a	*Bedded quartz +/-potassium-feldspar- phyric pyroclastic flow deposits and ash tuff deposits*
8b	*Block and ash flow/debris flow deposits*
	LOWER "L" SUCCESSION
7a	*Pyroclastic flow deposits*
7b	*Volcaniclastic sedimentary rocks*
	MATTABI SUCCESSION
6a	*Bedded quartz-phyric pyroclastic flow deposits*
6b	*Massive pyroclastic flow deposits*
	TAILINGS LAKE SUCCESSION
5a	*Debris flow / epiclastic sedimentary deposits*
5b	*Dacite ash deposits*
5c	*Andesite-dacite lava flows*
	BELL RIVER SUCCESSION
4a	*Rhyolite lava flows*
4b	*Pumice-rich pyroclastic flow deposits*
4c	*Sedimentary rocks and debris flow deposits*
	HIGH LEVEL LAKE SUCCESSION
3a	*Mesobreccia/megabeccia deposits*
3b	*Bedded quartz-phyric pyroclastic flow and ash deposits*
	JACKPOT LAKE SUCCESSION
2a	*Rhyolite lava flows*
2b	*Aphyric pyroclastic flow deposits*
	DARKWATER LAKE SUCCESSION
1a	*Basalt lava flows*
1b	*Scoria cone deposits*
1c	*Rhyolite lava flows*

Geological contact (defined, approximate)
Boundary of mapped area
Main roads
Winter roads
Synvolcanic fault ?
Post-volcanic normal / reverse fault ?
Thrust fault
Thrust fault (inferred)
Outcrop location
Strike and dip of bedding, top unknown (inclined) 80
Strike and dip of foliation (inclined) 70
Strike of foliation (dip unknown)
Schistosity (inclined) 60
Pillows, tops indicated by arrows
Drillholes start end
Vertical drill hole
Drillhole numbers 23-108
Ore body location
Breccia pipes

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1999: Geology, south Sturgeon Lake area, Ontario; Geological Survey of Canada, Open File 3642, scale 1:15 000.