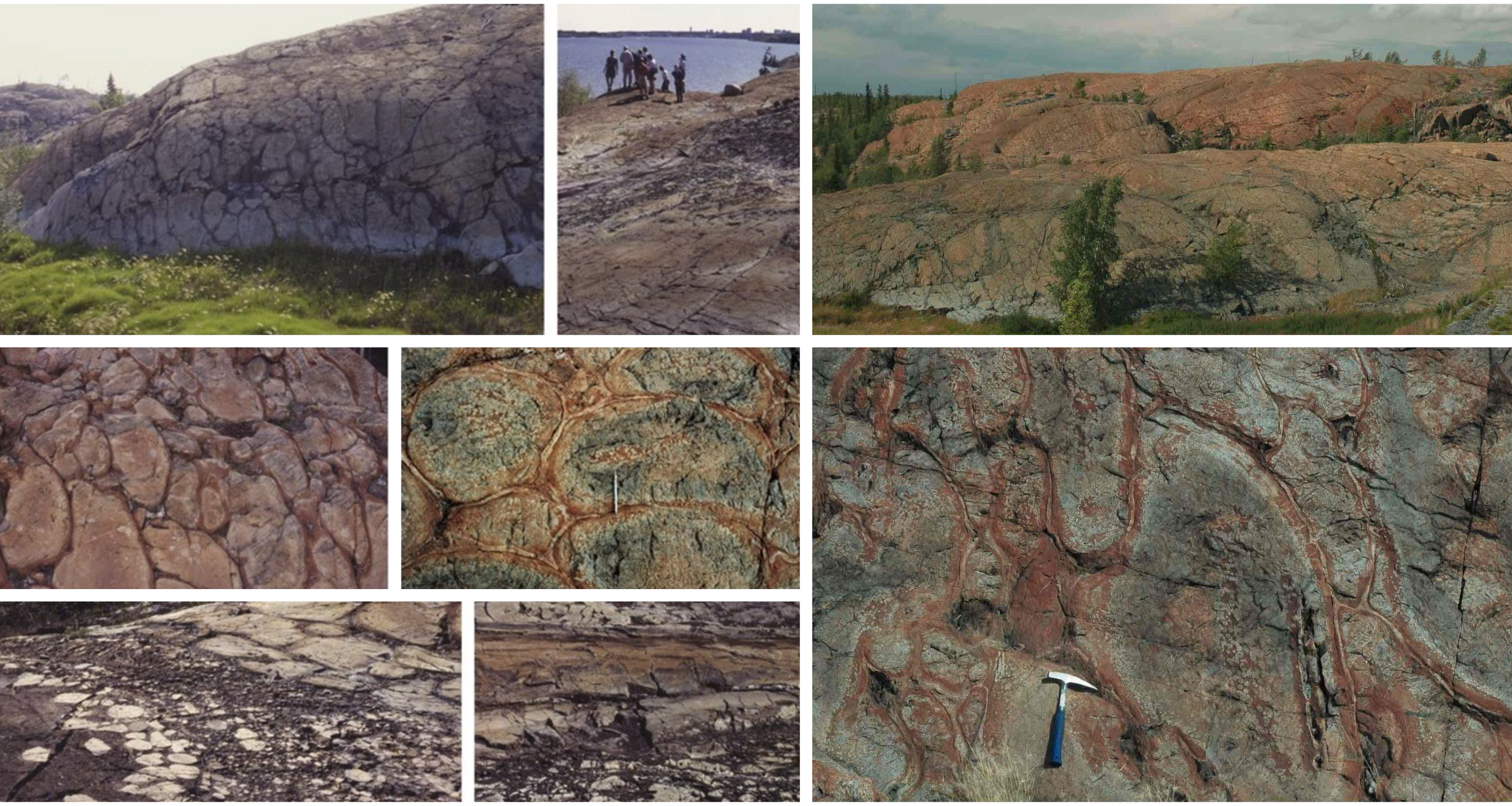
12TH INTERNATIONAL KIMBERLITE CONFERENCE

30 YEARS OF DIAMONDS IN CANADA

8–12 July 2024 • Yellowknife

12 IKC FIELD TRIP GUIDE



Slave Craton Geology

Field Trip Leader:
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Guide to the Giant Section

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Introduction

The 2.72-2.66 Ga Yellowknife greenstone belt (YGB) is one of the few volcanic belts in the Archean Slave Province to be subjected to detailed geological, geochemical, and geophysical studies. It includes a history of mafic and felsic volcanism, terrestrial and marine sedimentation, granite plutonism, contact and regional metamorphism, regional deformation, shearing, and transcurrent faulting. Superb exposures combined with a notable mineral endowment in the form of two major gold mines have resulted in the YGB becoming one of the best-mapped greenstone belts in the world. By the end of 2003, Yellowknife mines had produced a total of 13 million ounces (404 tonnes) of gold from ore bodies hosted in a set of anastomising shear zones (B. Hauser, pers. comm. 2004; McDonald et al., 1993).

Geological studies of the Yellowknife area over the years have been marked by changes in approaches and methodologies, resulting in new observations and insights on the YGB (see Stockwell, 1932; Helmstaedt et al, 2021). Milestones include the publication of the initial geological maps by Jolliffe (1938, 1942, 1946) that defined the principal rock units, and detailed mapping by J.F. Henderson and I.C. Brown (1966) that led to the recognition that modern geological processes could be understood through observation of Archean rocks (e.g., the formation of pillows). The quality and detail of the Henderson and Brown (1966) map makes it a valuable tool today. J.B. Henderson (1970, 1972, 1985) compiled the regional geology of the southwestern Slave Province. He noted that the YGB was situated at the western margin of a large sedimentary basin and was intruded by an equally expansive batholithic complex to the west. Helmstaedt and Padgham (1986a,b) summarized the results of their detailed mapping that extended Henderson and Brown's map area to cover the entire greenstone belt and adjacent rocks. Their summary contains the subdivision of YGB stratigraphy that is in current use. Geochronological data have generally supported the field-based observation that the mafic portion of the greenstone belt consists of a homoclinal sequence (Henderson, 1985), with no evidence of internal thrust duplication or large-scale dislocations (eg. Isachsen, 1992; Bleeker et al., 1999b; contrast with Kusky, 1989). Recently, the NATMAP and Lithoprobe programs have supported detailed mapping and large-scale geophysical, geochronological, and geochemical research programs that provide a Slave-wide framework for the YGB (Bleeker and Villeneuve, 1995; Davis and Bleeker, 1999; Ketchum and Bleeker, 2000; Bleeker, 2003).

Pre-YGB Intrusive Rocks

The nature of basement to the YGB is controversial. The first evidence of pre-YGB rocks in the Yellowknife area was derived from xenoliths in a diatreme breccia exposed in the Con Mine at Yellowknife, from which U-Pb zircon 207Pb/206Pb ages of 3.30-2.57 Ga were obtained (Nikic et al., 1975; 1980). However, field identification of in-situ basement rocks proved to be more problematic. Foliated and gneissic granitoid rocks located northwest of Yellowknife were regarded as sialic basement by Henderson (1985). He collectively termed these the Anton Complex and suggested that they were in fault contact with the YGB and intruded by the younger Defeat and Awry plutonic suites. Ages of 2642+15 Ma, 2648+12 Ma, and 2707+24 Ma for Anton Complex samples were, however, similar to or younger than the age of the supracrustal rocks (Düdas et al., 1990; Henderson, 1985). Subsequent work by Isachsen and Bowring (1997) provided the first confirmation of in-situ basement, with primary crystallization ages of 2929+1 Ma and 2945+1 Ma obtained for granitoid bodies at Dwyer and Bell lakes, respectively, in the northern part of the greenstone belt. These ages are comparable to those for dated gneissic rocks within the Sleepy Dragon Basement Complex, located on the east side of the Yellowknife basin (see Bleeker et al., 1999a and references therein; Ketchum et al. 2004).

The Kam Group

Kam Group is a predominantly northeast-striking homoclinal sequence of mafic flows and intermediate to felsic volcanic and volcaniclastic rocks that young toward the southeast (Padgham, 1979; Helmstaedt and Padgham, 1986a). The total thickness of the group is estimated to be 10-12 km (Helmstaedt and Padgham, 1986a). The true thickness may be somewhat less if the volcanic pile grew as a series of laterally prograding volcanic centres (Henderson, 1985). Nevertheless, the predominantly volcanic package was considered to be “too unwieldy to be described as a single formation” (Helmstaedt and Padgham, 1986a, p.454) and was raised to group status and subdivided into the Chan, Crestaurum, Townsite and Yellowknife Bay formations. According to Helmstaedt and Padgham (1986a, p.462), “the division was based on rock type, geographic position, variety and relation of syn- and subvolcanic intrusions, distribution of ore deposits and variations in bulk chemistry.”

Yellowknife Bay Formation

The Yellowknife Bay Formation hosts the major gold ore bodies of the Con and Giant mines. It conformably overlies the Townsite Formation and is best exposed along the shore of Yellowknife Bay (Helmstaedt and Padgham, 1986a). No complete section of the formation was defined by Helmstaedt and Padgham (1986a), although they considered it to include rocks from the top of the Townsite Formation to the Kam Point Sill. In the Giant Mine area, the formation is about one km thick, thickening to three km near the Con Mine. This thickness change has been partly attributed to excision by the Giant shear system (Helmstaedt and Padgham, 1986a), however primary depositional differences (Potts, 1988) or a regional unconformity at the top of the Yellowknife Bay Formation (Helmstaedt and Padgham, 1986a) represent other explanations.

The lower part of the Yellowknife Bay Formation consists of massive, pillow and pillow-breccia tholeiitic basalt flows (Baragar et al., 1979). Among these, the Negus and Yellorex flows are distinctively variolitic and are important for correlation of different sections (Renaud, 2000). Interbedded with the volcanic flows are thin, laterally extensive sedimentary horizons that change in character upward from cherty tuff and tuffaceous sedimentary rocks to turbiditic sandstone. The abundance of sedimentary horizons also increases upsection. A distinctive tuffaceous horizon, the Bode tuff (Henderson and Brown, 1966) can be traced across the many faults that dissect the central portion of the YGB. This tuffaceous conglomerate has well-rounded rhyodacite cobbles and boulders set in a tuffaceous to sandstone matrix. Falck (1990) determined that it formed by deposition of volcanic lithic fragments, tuffaceous material, and quartz-rich sandstone in a series of debris flows that moved downslope toward the southeast. Recognition that the Bode tuff is not a primary volcanic tuff prompted Padgham (1987b) to name this unit the Bode Member. Zircons from a felsic clast from the Bode Member have U-Pb ages of 2704+1 Ma whereas zircons from three felsic tuffaceous beds yielded ages of 2701+1, 2701+3, and 2702 +1 Ma (Isachsen, 1992).

Banting Group

The Banting Group, composed predominantly of felsic pyroclastic rocks, is located east of the Kam Group. Initially known as the "B Division" (Henderson and Brown, 1966), and later as the "Banting Formation" (Henderson, 1985), the unit is exemplified by a type section located between Walsh Lake and

Yellowknife River at the northern end of the YGB (Henderson, 1985). Although Banting Group rocks have been characterized as a calc-alkaline sequence (Cunningham and Lambert, 1989), recent geochemical studies have demonstrated that they follow a tholeiitic fractionation trend (Cousens, 2000; Cousens et al., 2002).

Mapping by Helmstaedt et al. (1980), Helmstaedt and Padgham (1986a), and Bailey (1987a, b) suggested that the Banting Formation could be divided into the Ingraham and the Prosperous formations, which raised the status of the package to group rank. Volcanic rocks exposed on islands in Yellowknife Bay were also proposed to belong to the Banting Group and are termed the Mirage Formation (Relf, 1988).

Jackson Lake Formation

The Jackson Lake Formation can be traced discontinuously from the northern end of the YGB to exposures south of the Kam Sill on the Sub Islands (636270E 6918450N). It comprises a diverse sedimentary assemblage ranging from heterolithic cobble conglomerate to well-bedded mudstone and wacke. Three main facies have been identified: a conglomerate-sandstone facies, a sandstone-argillite facies, and an argillite-sandstone facies (Mueller et al., 2002). The basal lithofacies is a 2 to 70 m-thick package of clast- to matrix-supported conglomerate with lenticular sandstone beds. This coarse-grained package is conformably overlain by and interfingers with medium- to coarse-grained sandstone with argillite drapes and laminated argillite layers. The sandstones differ from those of the Burwash Formation in their higher quartz content and lack of fresh feldspar crystals (Henderson, 1985).

Jackson Lake Formation conglomerates contain abundant granitoid clasts as well as volcanic and sedimentary clasts. The dominant clast composition at any one location is typically reflective of the underlying lithology (Mueller et al., 2002). The source of porphyritic granite clasts has not been firmly established, but geochemical work suggests that some originate from Defeat Suite plutons located west of Yellowknife (D.J. Atkinson, pers. comm., 1988).

The Giant Section

Located northwest of Yellowknife, the Giant Section is an extraordinarily well-exposed section through the Yellowknife volcanic belt on the west shore of Yellowknife Bay. The upper portion of the Yellowknife Bay Formation of the Kam Group comprises a 300 metre-thick sequence of pillow flows with gabbro dykes and sills (**Figure 1**). Magnificent exposures of typical Kam Group pillow lavas, pillow breccias and interflow sediments display numerous primary features (**Photo 1**). The dominantly basaltic Kam Group flows are overlain by mixed volcaniclastic sediments, ash flows and minor pillow basalts formerly assigned to the Banting Group and now considered to be the product of a continuation of Kam volcanism. The Giant Section is the one of the best localities where the relationship of the Yellowknife Bay Formation to the overlying Kamex Formation (informally defined at present) and the contact of the Jackson Lake Formation with these two volcanic units can be examined.

The lowermost unit at the Giant Section comprises the top 300 metres of the Yellorex Member. Variolitic pillow flows are exposed in steep ridges that are crosscut by gabbro dykes, commonly seen on ridge tops (**Photo 2, 3**) The pillows show a large variety of shapes and sizes, and examples with one or more interconnected buds are common. There is little interpillow material. The largest pillow at the Giant Section is over 100 metres long but most are no longer than 1 metre

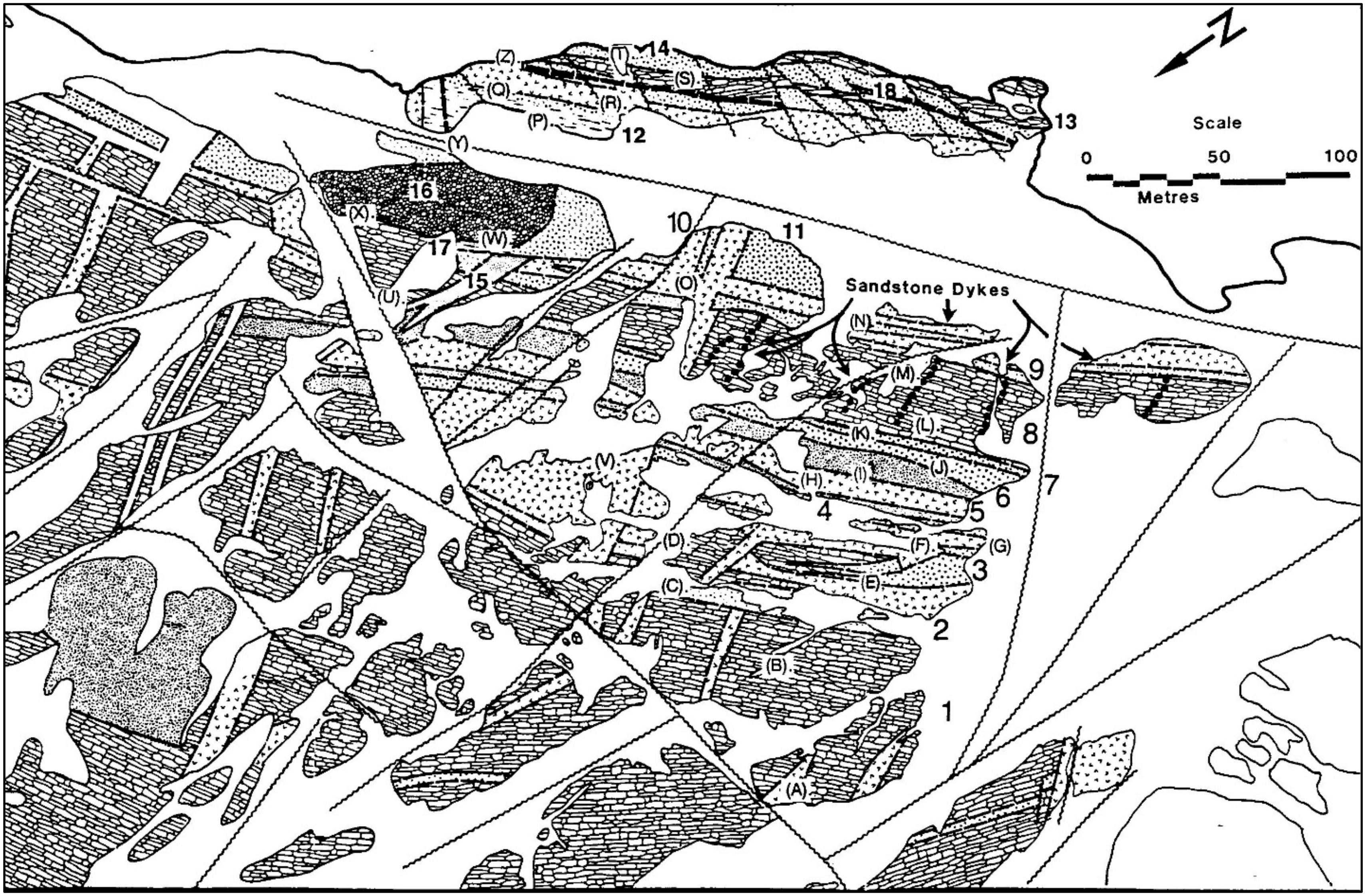

Figure 1: Geology of the Giant Section: 1. Yellorex flow, variolitic pillow basalt. 2. Bode member, conglomeratic tuff. 3. #5 Flow, pillow flow with breccia and drainage shelves. 4. Quartz-rich lithic sandstone. 5. Coarse metagabbro sill. 6. Sill- flow complex. 7. Turbiditic quartz-rich sandstone. 8. Pillow flow with sandstone dykes. 9. Turbiditic quartz-rich sandstone. 10. Multiple metagabbro dyke system. 11. Turbiditic sands. 12. Felsic volcaniclastics. 13. Pillow andesites. 14. Ignimbrite 15. Felsic dyke. 16. Jackson Lake Formation. 17. Weathered zone. 18. Late dyke. Modified from Padgham 1987.


Photo 1


Photo 2

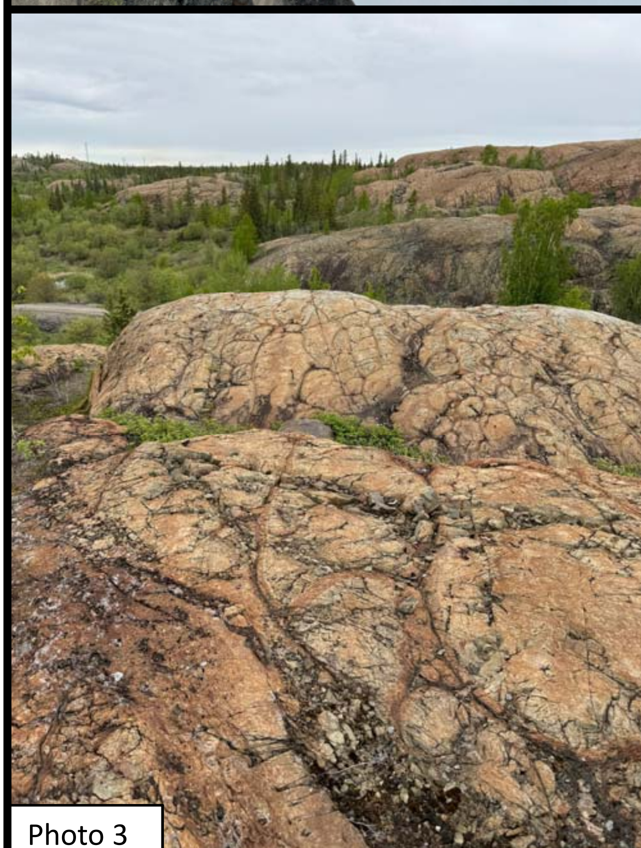
Photo 3


Photo 4


Photo 5

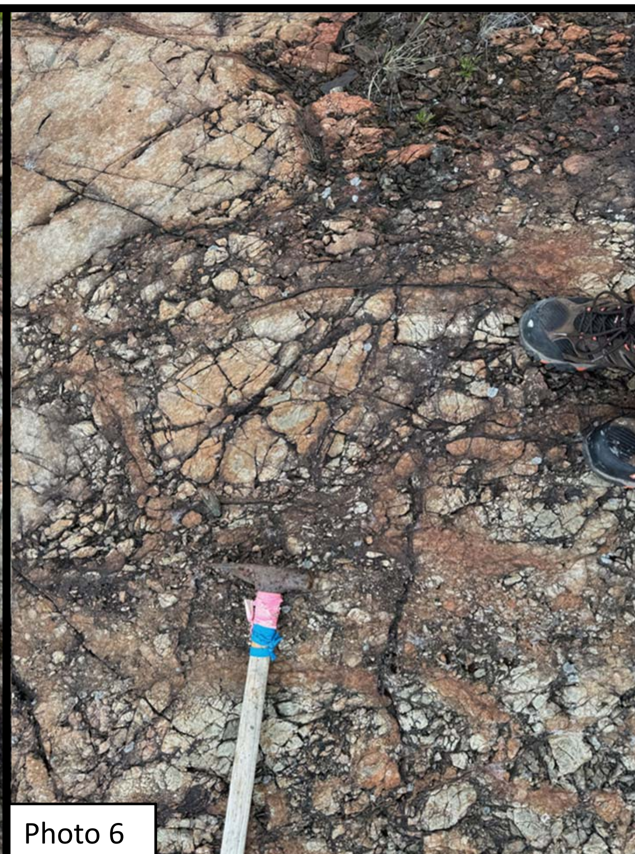
Photo 6


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Photo 8


Photo 9


Photo 10

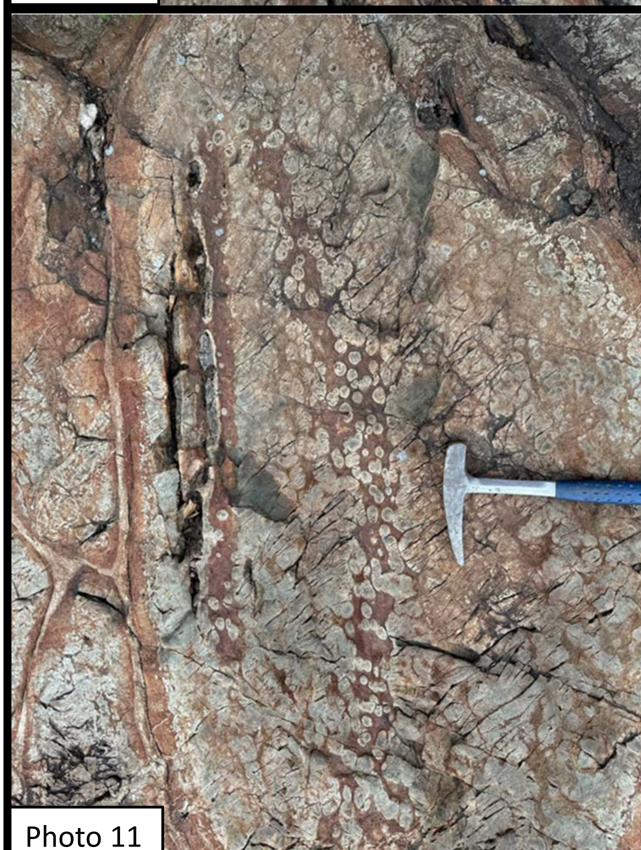
Photo 11


Photo 12


Photo 13


Photo 14

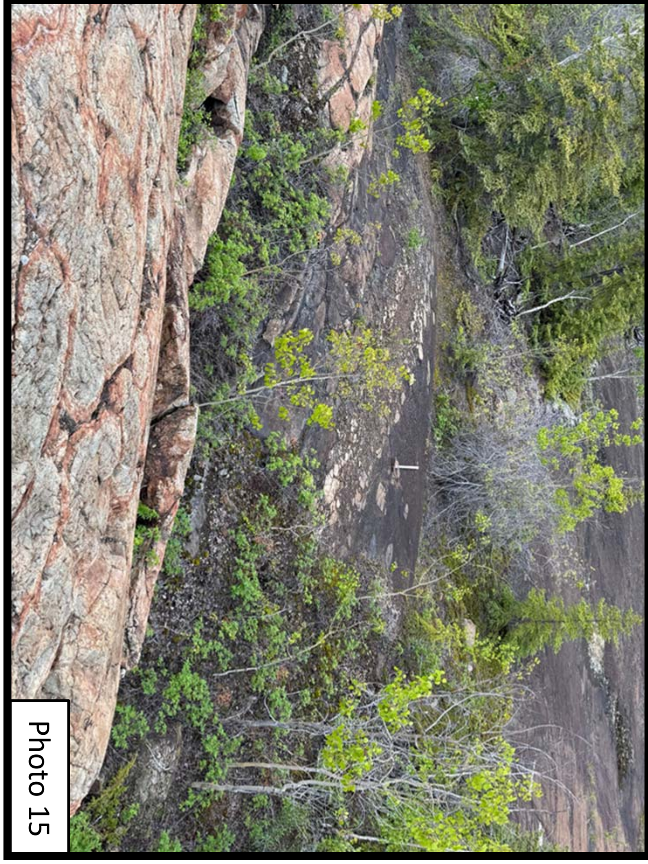
Photo 15


Photo 16

Large pillows of 30 and 100 metre lengths can be distinguished from massive flows by a selvage along the entire pillow rim (**Figure 1**, Location A). These large pillows or "mattress pillows" are rarely seen, in part because of incomplete exposures, but mainly because of the rarity of longitudinal sections oriented parallel to the flow direction (**Photo 4**). Measurement of directional flow indicators such as budding pillows (**Photo 5**) has demonstrated that most flows propagated towards the southeast (Padgham, 1987; Potts, 1988).
The outcrop also displays a cross-cutting breccia related to fumarolic activity. An influx of water into the hardening volcanic pile was heated to steam and resulted in an explosive escape structure. The margins of the fracture and breccia fragments are reddened due to the hydrothermal alteration which cuts across both pillows and flows (**Photo 6**). The upper portion of the fracture system was emptied of volcanic fragments and infilled with fine-grained sandstone (**Photo 7**). Bedding structures are apparent and align with nearby drainage shelves displayed in the pillows (**Photo 8**). The similarity of their orientations is suggestive of the original horizontal plane at the time of the volcanic pile's formation.

The pillows of the Yellorex Member are characterized by varioles of fine-grained epidote, hornblende and feldspar. The varioles tend to be more resistant to erosion than the matrix of the pillows and project out from the surface (**Photo 9**). Typical varioles are clustered around the rims, which are 1 to 3 centimetres thick on average (Henderson & Brown, 1966).

Two distinct flows of variolitic pillow lava (**Figure 1**, Location B) are exposed at the base of the Giant Section (**Photo 10**). Both flows display budding pillows but only one large pillow is apparent in the upper flow. The upper flow can be separated from the lower flow on the basis of thicker pillow rims and a distinct, widely-spaced hexagonal jointing pattern, normal to the flow top, that may have formed by contraction during cooling. Quartz pods occupy isolated pillow interstices and lava drainage shelves have developed where magma drained or partly drained from a lava tube (**Photo 11**). The pillow lavas are cut and metamorphosed by mafic dykes displaying a variety of features that suggest that the dykes were nearly contemporaneous with the pillow flows (**Photo 12**). The zoned dykes have rounded vesiculated margins that appear to bow into the centre of pillows (**Photo 13**). Thin apophyses of the mafic intrusion follow irregular paths and do not conform to a single structural stress field (**Photo 14**).

The variolitic lavas of the Yellorex member are overlain by the Bode member, a tuffaceous conglomerate with abundant rhyodacitic clasts (**Photo 15, 16**) (**Figure 1**, Location C). Initially identified as a "cherty-tuff", turbiditic characteristics have been observed in the Bode member outside of the Giant Section (**Photo 17**). In the Bode member, rounded to sub-rounded, phyric rhyodacite cobbles (**Photo 18**), as well as fragments of variolitic pillows (**Photo 19**), float in a fine-grained matrix (**Photo 20**). Graded bedding and cross bedding are present in the matrix which contains flattened hyaloclastic lapilli. Many of the rhyodacite cobbles have an altered rind that was originally thought to represent a reaction with the matrix. In places however, the boulders have been fault-offset and the faulted surfaces do not display the alteration. Instead, it is thought to represent the product of xenolithic clasts being milled in a volcanic vent prior to eruption. The boulder conglomerate fines to the southwest, suggesting that the source of the felsic clasts was to the northeast. At the Giant Section, the coarse nature of the Bode member further suggests that a central vent was nearby.

The Bode member marks an important depositional change within the Yellowknife Bay Formation. Below the Bode member, massive and pillow flows typical of the Kam Group predominate whereas above, quartz-rich turbidite sands are interlayered with coarse gabbro sills and distinctive vesiculated flows. The Bode member represents a series of lahar deposits and may mark the beginning of a transition to the more intermediate volcanism of the Kamex formation.

Resting on the Bode member is a distinctive pillow flow unit (**Figure 1**, Location D), informally termed the #5 flow, containing many features suggestive of lavas more fluid than the Yellorex Flows. The pillow rims are thinner, and vesicles are abundant along pillow selvages. Repeated vesicular crusts form long drainage shelves representing sequential lava drainage and chilling (**Photo 21**). Successive flows at slightly lower levels permitted numerous thin crusts to form within the lava tubes (**Photo 22**). Narrow irregular dykes cutting the pillows may represent magma that was squeezed out of lower pillows and acted as local feeders to higher pillows (**Photo 23**) (Padgham, 1987). Alternatively, the dykes may extend from a high-level intrusion that was emplaced while the volcanic flows were still relatively warm and somewhat plastic in nature.

An excellent example of a large feeder tube is preserved in this flow. This tube exhibits abundant branching pillows, and the tube can be traced back to a feeder dyke (**Photo 24**). The top and southern end of this flow is coarse grained and is typical of dykes and sills of the Giant Section. This part of the flow is largely massive with no features other than pillow rims. It may be a large feeder tube to pillows located south of the Giant Section.

Locally, the basal unit of this complex flow unit is a well-developed pillow breccia with abundant hyaloclastite. In this area, the contact of the large mafic dyke changes orientation from east-west to north-south over a lateral distance of about 50 metres. The new orientation of the intrusive rock is parallel to the pillow flow suggesting that the dyke is feeding a sill structure. Thirty meters farther along the dyke there is a pillow breccia that merges into a pillow flow to the south. (**Figure 1**, Location E) (**Photo 25**). The breccia consists of angular fragments spalled from the outer crusts of pillows (**Photo 26**. These distinctive features suggest that the #5 flow complex is different from the typical Kam-type flow, more closely resembling flows of the Banting Group and the Duck Formation (Padgham, 1987).

On top of the #5 complex flow is a light grey tuffaceous sandstone (**Figure 1**, Location F) that weathers whitish with a pinkish cast, possibly as a result of contact metamorphism due to the 8 metre-thick overlying gabbro sill (**Figure 1**, Location G) that has a chilled margin against the sandstone. The gabbro displays subequant amphibole pseudomorphs of pyroxene up to 5 millimetres in diameter (**Photo 27**). The groundmass consists mostly of altered plagioclase. Central portions of the sill contain relatively coarse clots of amphibole which fine upward and downward toward the sill margins. The top of the gabbro sill is chilled against an overlying tuffaceous sandstone, which has also been baked on top by another gabbro sill (**Photo 28**). The second sill (**Figure 1**, Location H) has a predominantly coarse core but grades through fine and coarse phases several times, implying multiple magma pulses during emplacement. The sill grades upward into an amygdaloidal massive flow where the contact zone is marked by a string of epidote pods up to 10 centimetres in diameter (**Photo 29**) (**Figure 1**, Location I). The irregular top of the massive flow is covered by pillow breccia (**Photo 30, 31**) (**Figure 1**, Location J).

A sandstone bed (**Figure 1**, Location K) overlies the breccia and also encloses some of the breccia fragments (**Photo 32**). Isolated pillows in the breccia contain inclusions of sandstone. Some are angular sandstone fragments (**Photo 33**) which may have originated as rip-up clasts, whereas in others, the sandstone forms rounded sand inclusions, which may have been incorporated as a wet slurry. The coarse sandstone is well bedded and overlain by pillows which locally depress the bedding, demonstrating that the sandstone was not lithified at the time of lava extrusion (**Photo 34**). In places, the sand occupies interpillow spaces. Laminations within the sediment show that the sand was injected upward between the pillows.

Pods of sand at a common horizon within the pillow flow (**Figure 1**, Location L) demonstrate that sand transportation and deposition was contemporaneous with pillow formation. Above this horizon, pillow interstices are filled with sandstone and some pillows "float" in the sediment. Cross bedding in a number of these interpillow enclaves indicates that the sandstone was deposited by a strong current. Preservation of pillow rims suggests rapid deposition, but the absence of pillow breccia is unusual. The currents that deposited the sand during waning flow conditions might have swept the breccia away when the currents were at peak strength, or breccia simply may not have formed (Padgham, 1980).

Photo 17

Photo 18

Photo 19

Photo 20


Photo 21


Photo 22


Photo 23


Photo 24

Photo 25

Photo 26

Photo 27

Photo 28


Photo 29


Photo 30


Photo 31


Photo 32

Towards the top of the pillow flow (**Figure 1**, Location M), elongate and complexly-budded pillows reach 4 and 5 metres in length. Many buds have incomplete selvages, partially closing them off from the main pillow body. The pillow flow is cut by six large sandstone dykes, some of which coalesce with a sandstone bed overlying the pillow flow; all of the dykes wedge out before reaching the lower sandstone (**Photo 35**). At the top of the flow, sandstone fills the interstices and quartz-rich greywacke rests conformably on the flow (**Photo 36**).

The upper sandstone is the first bed in a thick sequence of coarse-grained sandstone interlayered with irregular coarse-grained gabbro sills (**Figure 1**, Location N) that resemble the sills observed lower in the section. The gabbro sills locally crosscut the sand bedding, apophyses of chilled gabbro extend into the sand, and chilled margins completely surround the sills (**Photo 37**). Hyaloclastic breccia, as would be expected of extrusive bodies, is absent. This zone is therefore interpreted as a near-surface intrusion into wet sands intercalated with pillow flows. Sill intrusion probably mobilized sediment into small clastic dykes that cut the base of the sills. Younger sills tend to develop above older ones because penetration of soft sediments is easier than penetration of sediments compacted by older sills (Einsele, 1985). The sandstone is overlain by graded beds of fine-grained sandstone and cherty tuff. These beds have been intruded by a large gabbro dyke (**Figure 1**, Location O) which fed a network of smaller dykes and sills (**Photo 38**).

The entire sequence exposed at the Giant Section is cut by a large set of gabbro dykes and sills (**Photo 39**). At the northern edge of the sandstone-sill complex is a 10 to 50 metre-wide irregular sheeted gabbro dyke (**Figure 1**, Location O). Based on their positions and lithologies, these dykes have been proposed as feeder dykes to the volcanic edifice (Padgham, 1987; Padgham, 1980; Henderson & Brown, 1966). The dykes, which can be traced for over 200 metres, display a variety of features suggesting intrusion into sediments that were not far below the ocean floor. These include an abundance of vesicles and selvage-like margins with associated perlitic fractures, similar to selvages around nearby pillows, which were clearly formed subaqueously (**Photo 40**). There is a common assumption that most dykes in a volcanic system are feeder dykes or dykes that reach the surface to form flows, but observations have not supported such assumptions. Of more than 21,000 dykes in the Columbia Plateau, only a few are connected to the basalt flows (cf. Gudmundsson, 1984). Thus, the exposure at the Giant Section, where there is a clear relationship between dykes, flows and sills, is unusual.

Sheeted dykes cut the Yellowknife Bay Formation north and south of the Giant Section and many of these intrusions (**Figure 1**, Location V) have multiple internal chills representing separate magma pulses (**Photo 41**). The large gabbro dyke displays evidence of multiple intrusion events. Coarse-grained gabbroic sections are commonly interspersed with fine-grained dyke margins. The intrusions are not consistently symmetrical. A sampling traverse across the dyke revealed two distinct compositions. The first contains ca. 0.5 % TiO2 and geochemically matches the surrounding pillow flows. In contrast, some of the chilled dykes contain over 1% TiO2. Pillow flows with a similar composition are found only much higher in the stratigraphic sequence on islands in Yellowknife Bay. Studies of modern and Tertiary volcanic terranes have shown that dykes follow the path of least resistance. In a still-cooling volcanic pile, this path is often the central parts of thick lava flows which have not completely solidified, or in the case of the Giant Section, through unlithified sediments. In more solidified flows, the path of least resistance is along sub-vertical cooling joints. Pulses of magma can repeatedly split pre-existing intrusions to produce multiple dykes (Gudmundsson, 1984).

The eastern limit of the main outcrop is composed of sandstone lenses interdigitated with gabbro. Beyond the break in outcrop, all rocks were formerly ascribed to the Ingraham Formation of the Banting Group. However, geochemical work by B. Cousens suggests that these rocks do not belong to the Banting Group but are instead a continuation of Kam Group volcanism as it becomes more felsic in composition (Cousens, 2000; Cousens et al., 2002). Rather than dilute the expression of the Yellowknife Bay Formation by increasing the thickness of the formation into an unwieldy unit, it has been suggested by Falck, Cousens and Isachsen (1999) that a new formation called the Kamex formation be defined.

The Kamex rocks exposed at the Giant Section start with a massive tuff (**Figure 1**, Location P) which grades into laminated siltstone (**Photo 42**). The tuff is crosscut by a vein network of fine grey-tan alteration (**Photo 43**). The ash probably fused immediately after deposition and cold water crackled the glassy ash, allowing water to seep along the newly-formed fractures. The water was heated, and magnesium was introduced along the fractures while silica was removed. The silica was redeposited as thin chert beds when the heated water mixed with cooler seawater.

Overlying the locally fine-grained cherty and locally hematite-rich layers is an air fall tuff (**Figure 1**, Location Q) containing fragments of lapilli size and larger. Intruding this tuff is a massive sill (**Figure 1**, Location R), fed by a multiple dyke similar to those in the upper Kam Group. The upper margin of the sill is vesicular but without a breccia cover. Above the sill, the tuff contains large pumice fragments that weather preferentially due to their substantial calcite content.

The next unit is composed of lavas in the form of "mattress" pillow andesites (**Figure 1**, Location S) with concentric banding (**Photo 44**). The pillows are fine grained with grey-green layers at intervals of 2 to 5 centimetres. (**Photo 45**) The concentric layering may have formed as cooling contraction fractures, or by shear between congealed lava and more mobile hotter fluids in the pillow cores. As the layering is incomplete towards the bottom of the flow, internal flow shearing has been proposed but quenching has also been suggested as a more plausible explanation. In the lowest part of the flow, pillows appear to be absent, but the layering is well developed in what is either a massive flow or a very large pillow. The interstices between the pillows contain numerous angular fragments of spalled pillow rim. Overall, this unit is easily differentiated from the typical Kam pillow flows (Padgham, 1987).

In close association with the pillow flow is a welded ash tuff identified as an ignimbrite (**Figure 1**, Location T). The ignimbrite is light coloured with greenish to yellow fiamme-like lenses (**Photo 46**). Thin sections of the welded tuff show that the yellowish fiamme consist mostly of felted sericite in a groundmass of fine-grained sericite, carbonate, epidote and small grains of feldspar. Broken high-quartz crystals, 2-5 millimetres in diameter, and rare, highly-altered feldspar crystals form nearly 20% of the groundmass (Padgham, 1980).

The ignimbrite has been interpreted as a subaerial deposit, but the under- and overlying pillow flows suggest a subaqueous origin (Padgham, 1987). The distinction between subaerial and subaqueous deposits is not always easy to determine because evidence is commonly indirect. Primary structures and structure sequences are not valid criteria and conclusions are often based on the presence of pillows in the sequence. The most diagnostic feature of subaerial flows was thought to be flattened, welded vesicular fragments, but under higher water pressures, welding is possible at lower temperatures. Subaqueous debris flows are finer grained and have a higher percentage of matrix than their subaerial counterparts. The bed thickness of subaqueous debris flows is commonly 3-10 times greater than the maximum fragment size whereas in subaerial deposits, bed thickness is only 2-4 times greater (Wright et al., 1980; Fisher, 1982; Lajoie, 1984).

The felsic ash beds of the Kamex formation may have been fed by felsic dykes that cut the mafic flows of the Kam Group (**Photo 47**). Although rarely observed within the Giant Section, these dykes (**Figure 1**, Location U) have irregular margins, are commonly less than 1 metre wide, and have silicified their host mafic rocks.

The Jackson Lake Formation crops out north of the large multiple dyke. The Kam Group-Jackson Lake Formation contact can be examined at only a few locations, of which the Giant Section is one of the best. At this controversial contact, the Jackson Lake Formation (**Figure 1**, Location W) appears to lie beneath


Photo 33


Photo 34

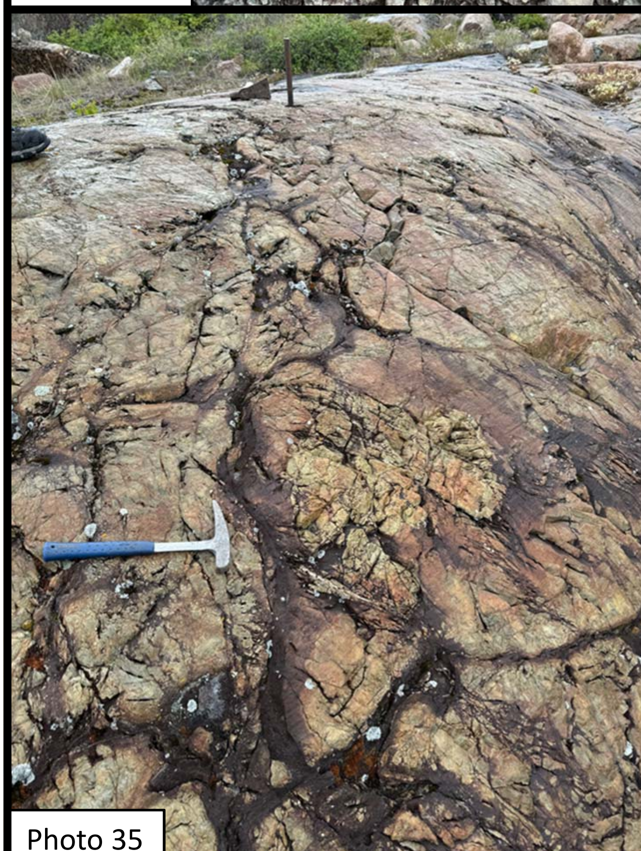
Photo 35


Photo 36

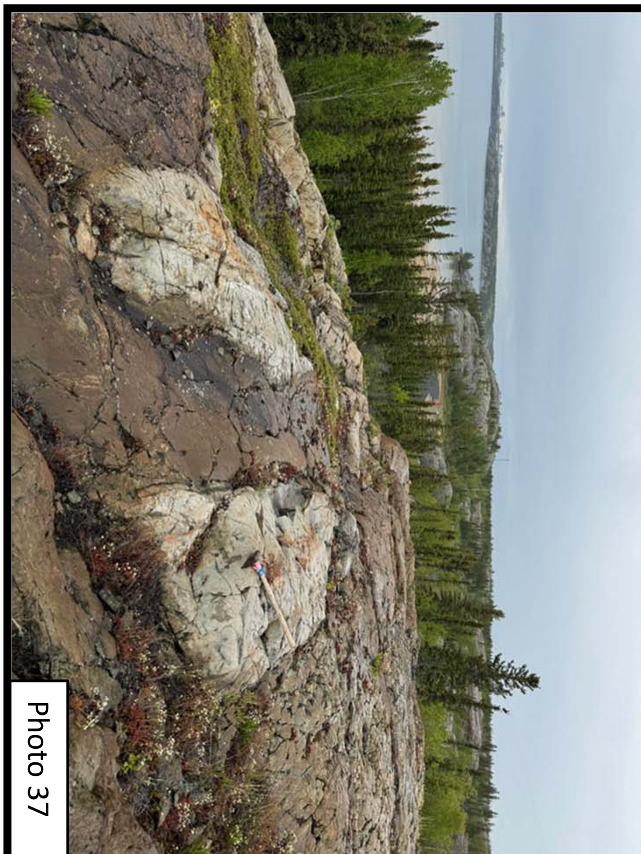
Photo 37


Photo 38


Photo 39


Photo 40

Photo 41

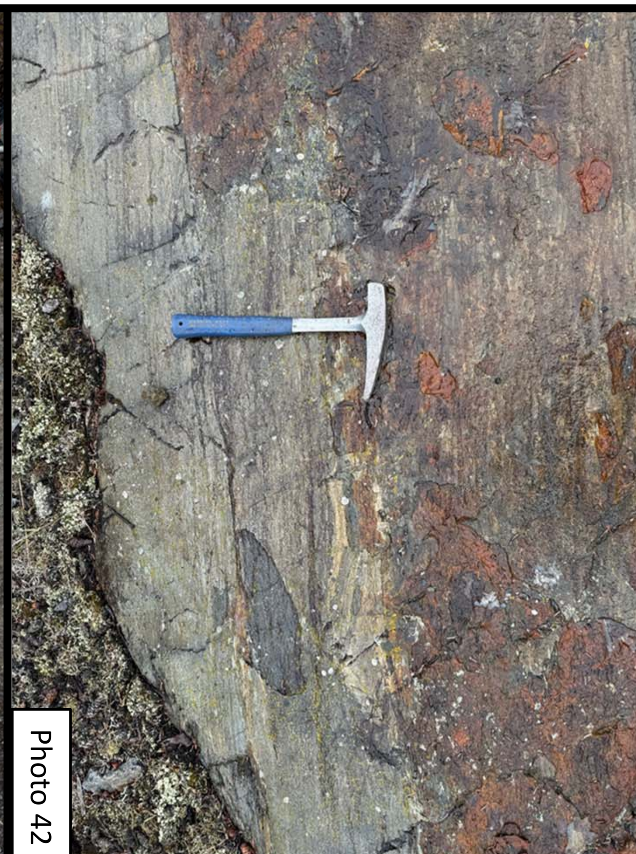

Photo 42

Photo 43

Photo 44

Photo 45

Photo 46

Photo 47

Photo 48

deposits previously identified as part of the Banting Group. This relationship led to speculation that the Jackson Lake Formation may be stratigraphically older than the Banting Group (Henderson, 1985). However, geochronological analyses and structural examinations confirm Helmstaedt and Padgham's (1987) revision of the stratigraphy, such that the Banting Group is older than the Jackson Lake Formation.

The Jackson Lake Formation consists of polymictic conglomerate containing a predominance of dark volcanic clasts and an abundance of pinkish granitic clasts (**Photo 48**). Greyish to black granitoid clasts with a porphyritic aspect are also common in the matrix of quartz-rich coarse-grained sandstone within this formation. The granitoid clasts probably were eroded from the upper portions of sub-volcanic intrusions of the Western Plutonic Complex (D. Atkinson, 1989, personal communication). The cobbles are distinctly flattened, and two foliations are discernible.

Below the conglomerate is a thin zone of sandstone which lies on partially-disintegrated pillows, interpreted as a regolith (**Figure 1**, Location X) (**Figure 2**, Stop 1). In places, the rock is highly altered and silicified due to deep weathering along fault zones. Elsewhere in the belt, the conglomerate lies directly on pillows which were only moderately affected by paleoweathering (**Photo 49**) (see **Figure 2**). The angular unconformity is folded, displaying an S-fold asymmetry (**Figure 2**). Rocks on both sides of the Jackson Lake Formation belong to the Kam Group (**Photo 50**). The foliation axial planar to the fold is defined by the flattening of clasts and is interpreted as S2. The F2 fold (a syncline) plunges shallowly to the north. The F2 fold is overprinted by a later foliation correlated with S4. The S3 foliation is not observed at the Giant Section because mica-rich (pelitic) beds in which the S3 foliation preferentially develops are absent. On vertical sections, the steep stretching of the clasts (L2) is evident.

At the next stop (**Figure 1**, Location Y) (**Figure 2**, Stop 2), both the conglomerate and sandstone of the Jackson Lake Formation are exposed. The S2 and S4 foliations are well developed in the sandstone beds. S4 is a spaced foliation oriented clockwise to bedding, striking ~050°, and is defined by a preferred alignment of micas. The S2 foliation, defined by the deformation of quartz grains, is seen in microlithons. The presence of randomly-oriented, microscopic-scale chlorotoid grains is ubiquitous in the conglomerate and sandstone exposed in the vicinity of the Giant Section as well as in drill core to the east underneath Yellowknife Bay. Gabbroic dykes continue from the Yellowknife Bay

Formation into the Kamex Formation but where the Jackson Lake Formation is clearly identified, the dykes are truncated by the erosional unconformity.

As the Jackson Lake Formation rests unconformably on eroded upper Kam Group, faults have been hypothesized to account for the dislocation seen at the Giant Section. A fault (**Figure 1,** Location Y and **Figure 2**, dotted line) in the covered zone is suggested by locally-intense shearing of the Jackson Lake Formation and abundant quartz veinlets (Padgham, 1987). An important observation is that the Yellowknife River Fault Zone is not present at the Giant Section. In all other localities, the western margin of the Banting Group (in contact with the Jackson Lake Formation from Yellowknife Bay to Greyling Lake and with the Kam Group from Bluefish Lake northward) is highly strained. However, if the Yellowknife River Fault Zone is present at the Giant Section, it must be confined to a narrow-covered area, which would be an uncommon width for this fault zone.

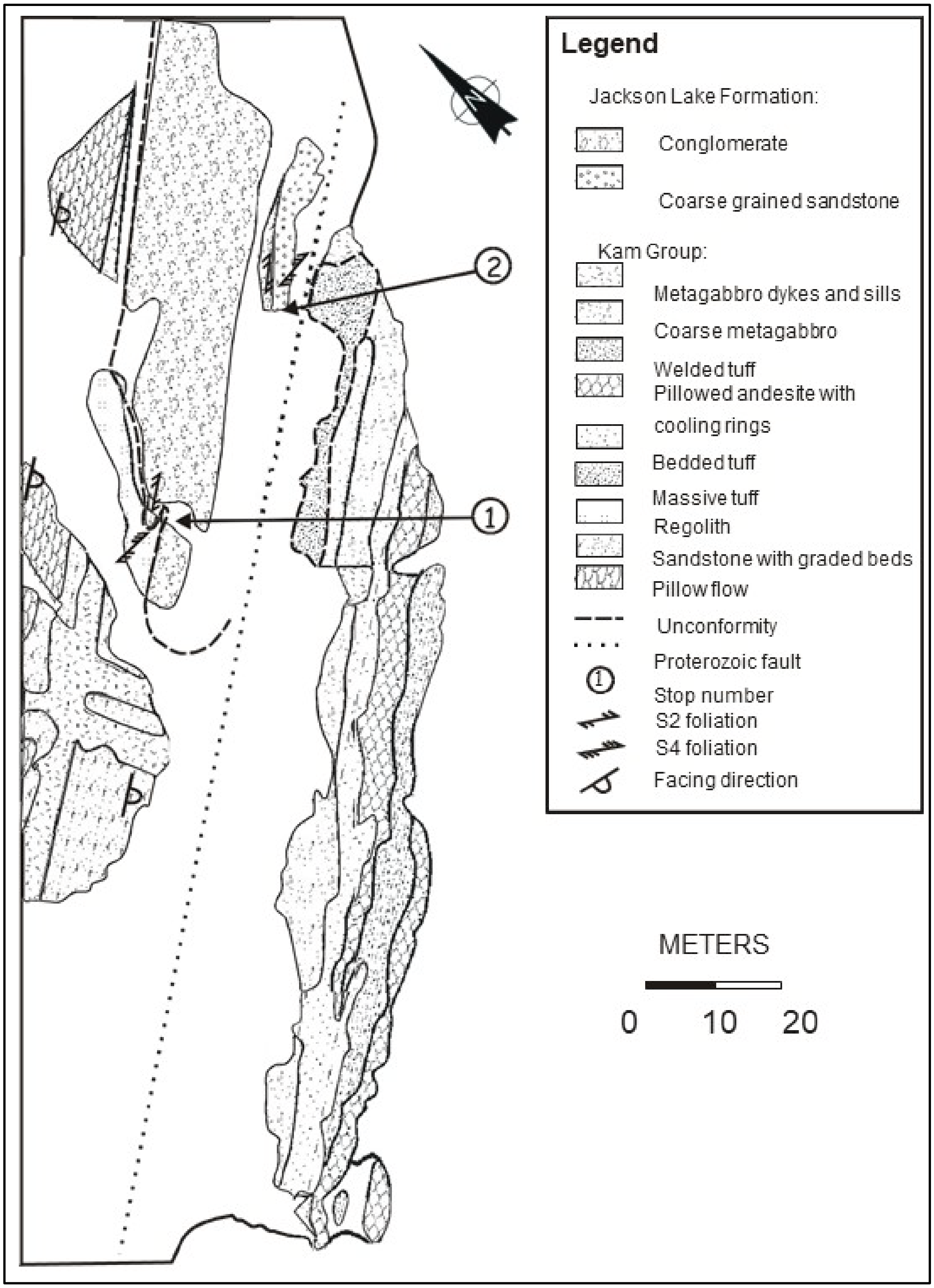

Figure 2: Simplified geology map of the southeast portion of the Giant Section. The unconformable contact between mafic volcanics of the Kam Group and the Timiskaming-like conglomerate and sandstone of the Jackson Lake Formation is exposed (Martel, 2003).

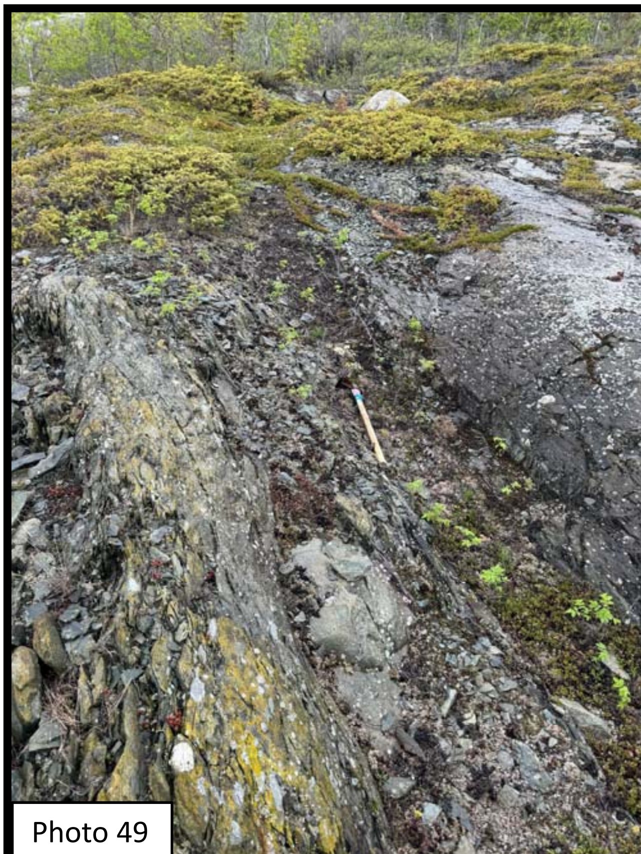

Photo 49

Photo 50

Photo 51

Photo 52

Possibly the youngest rock in the Giant Section is a thin, fine-grained mafic dyke rich in epidote and pyrite that cuts parallel to the shoreline through the shoreline outcrop (**Photo 51**) (**Figure 1**, Location Z). The diabasic nature of this dyke is distinct from other mafic intrusions of the area and distinguishes it as a young, most likely Proterozoic dyke (**Photo 52**) (Padgham, 1987).

Age Constraints

The Giant Section provides an opportunity to pair a superbly-exposed, low grade segment of the Yellowknife greenstone belt with direct and indirect age dating constraints. These constraints have been described by Bleeker (2007) and a summary of this description is provided below. All cited ages are based on uranium-lead (U-Pb) zircon dating.

Although much of the Giant Section is not amenable to U-Pb dating, two lithologies have yielded primary ages. A rhyodacite boulder from the Bode Member has an igneous crystallization age of 2704 ± 1 Ma (Isachsen, 1992), constraining the maximum deposition age of this unit to ca. 2704 Ma. Higher in the stratigraphy along the shore of Yellowknife Bay, a quartz-porphyritic ash flow tuff is dated at 2701 ± 4 Ma (Davis et al., 2004). This result supports the earlier conclusion of Cousens (2000) and Cousens et al. (2002) based on geochemical and isotopic evidence that these shoreline exposures belong to the Kam Group (Kamex formation) and are not part of the younger Banting Group as previously assumed.

Various age constraints for the Jackson Lake Formation broadly pin its deposition age to ca. 2600 Ma. A granite cobble from this formation is dated at 2605 ± 6 Ma (Isachsen, 1992; Isachsen and Bowring, 1994) and detrital zircons analysed by SHRIMP (sensitive high-resolution ion microprobe) have two predominant age peaks at 2700 Ma and 2616 Ma (Sircombe and Bleeker, unpublished data). The latter results were obtained for a sample collected from the Sub Islands in Yellowknife Bay, 14 kilometres south of the Giant Section. Conventional U-Pb dating of this sample by Davis et al. (2004) yielded similar results.

In combination with regional U-Pb age data, the synclinally-folded geometry of the Jackson Lake Formation observed in the Giant Section allows the timing of regional deformation events to be broadly constrained. F1 folding and tilting of Kam Group strata occurred at ca. 2640 Ma, some 60 million years after the Giant Section's basalt flows and volcaniclastic rocks were deposited. D2 deformation and F2 folding (the predominant Jackson Lake folding event) is regionally constrained to ca. 2596 Ma, the emplacement age of a syn-kinematic plutonic suite (Davis and Bleeker, 1999). This information, combined with the ca. 2605 Ma maximum deposition age for the Jackson Lake Formation (Isachsen, 1992), provides a roughly 10 million year window for deposition, consolidation and folding of this sedimentary package. All these events presumably are an expression of an active D2 orogenic regime at 2600 Ma. The age of the Jackson Lake basal unconformity is less certain. Although it could be older, the high-energy fluvial environment in which the Jackson Lake Formation was deposited suggests that the unconformity surface likely is of similar age.

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