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DEPARTMENT OF ENERGY, MINES AND RESOURCES

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PRELIMINARY NOTES ON THE HURWITZ GROUP, PADLEI MAP-AREA, NORTHWEST TERRITORIES

(Report and 3 figures)

R. T. Bell

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ABSTRACT

Studies of the Hurwitz Group at the northeast end of the Rankin-Ennadai belt have disclosed a pocket of older pyritic, mildly radioactive sedimentary rocks similar to those farther west at Montgomery Lake. Basic data on these and associated rocks are presented along with a figure showing the distribution of these rocks in the Padlei map-area.

The lower formations of the Hurwitz Group are formally defined: Padlei Formation, Kinga Formation, including Maguse and Whiterock Lake Members, and Ameto Formation, including Happotiyik Member.

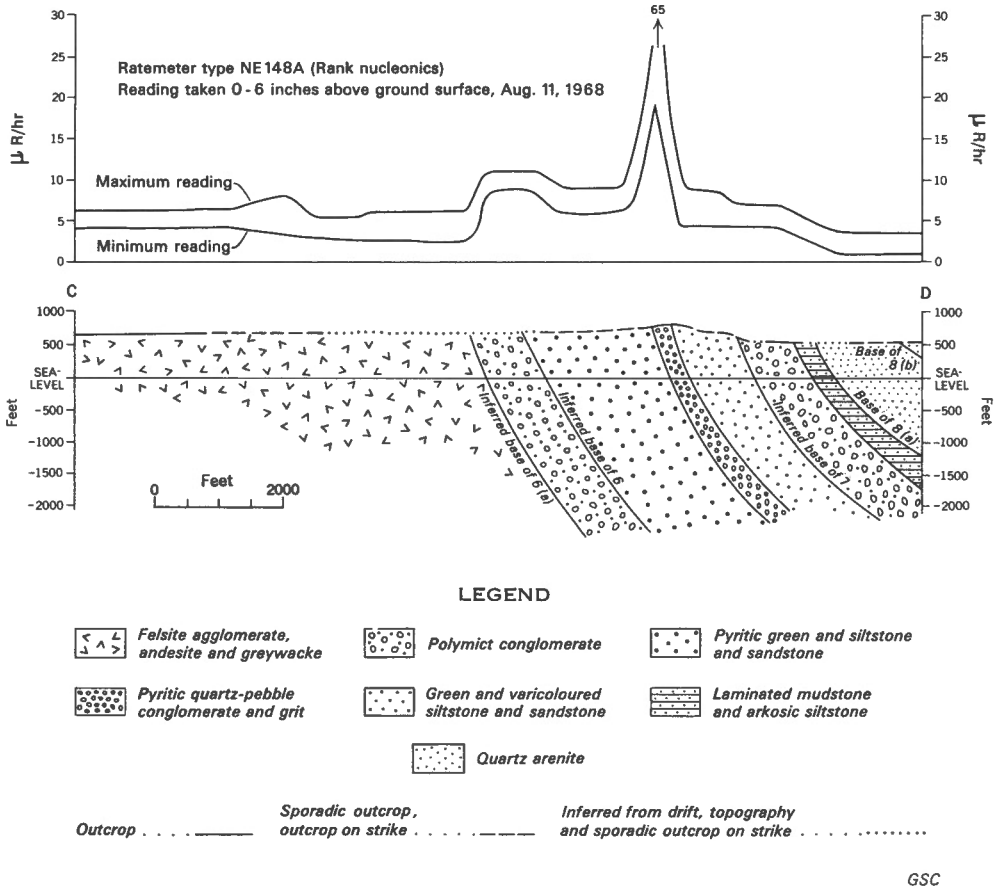

Figure 1. Typical section southeast flank of Padlei belt with scintillation ratemeter data.

PRELIMINARY NOTES ON THE HURWITZ GROUP, PADLEI MAP-AREA, NORTHWEST TERRITORIES

INTRODUCTION

The area is about 240 miles north of Churchill, Manitoba and lies within the region mapped in 1952 by the first helicopter-supported survey of the Geological Survey of Canada (Lord, 1953; Wright, 1967). This and adjacent areas were covered by a combination of helicopter, foot, and boat traverses during the summer of 1968 (Bell, 1969). The southeast and south-central parts of the accompanying map-area were studied only with helicopter traverses in late June when high water and scattered snow patches restricted observation. Information from earlier operations (Lord, 1953; Eade, 1966) has been used. Accumulated data permit a detailed presentation of the Padlei belt of Hurwitz strata and adjacent Archean rocks.

The author was ably assisted by Dr. J. L. Talbot of Lakehead University and by student assistants R. K. Anderson, J. W. E. Lau, T. M. Robertson, and B. C. Wilson. Equipment and fuel were moved to the field during the preceding winter by TransAir Limited. Transportation in the field was supplied under contract with Athabaska Airways and Lambair Limited. The author wishes to acknowledge the excellent services of the air crews.

Topography on each side of the Padlei belt is low and undulating. Quartzites in the belt form ridges and prominent hills. North of the belt rocks are well exposed, but extensive areas of drift restrict observations south of the belt.

Informal stratigraphic subdivisions for the Hurwitz Group proposed in an earlier paper (Bell, 1968) are modified and formalized.

GENERAL GEOLOGY

The area lies within the Churchill (structural) Province of the Canadian Shield. The oldest rocks comprise volcanic, sedimentary, and intrusive rocks and are part of a well-preserved Archean subprovince, part of the Hudson protocontinent of Goodwin (1968). The volcanic and clastic rocks show an aggregate easterly to northeasterly structural alignment and in general have an imposed dominant penetrative cleavage with a northeasterly trend which together with the Padlei synclinorium is typical of the Hudsonian Orogeny in this area.

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Archean

Kaminak Group

Volcanic rocks (unit 1) and sedimentary rocks (unit 2) are the oldest rocks in the area. Davidson (in press) has proposed the name Kaminak Group for similar rocks in the area to the northeast.

Massive and pillowed fine-grained andesitic or basaltic flows and associated metagabbro sills and flows are characteristic of unit 1a. Pale green and grey, siliceous extrusive rocks, including felsites, agglomerate, breccia, and tuff are typical of unit 1b. The remaining volcanic terrain is undivided (unit 1) and largely composed of pillowed and massive andesites and thick agglomerate units. Locally greywacke and mudstone beds 2 to 25 feet thick are present. South of Kinga Lake felsites and quartz porphyries are abundant but have not been distinguished on the accompanying map.

Greywacke, slaty-cleaved mudstone, iron-formation, conglomerate, and tuff or tuffaceous greywacke are typical of unit 2. Medium- to coarse-grained, greenish grey to grey, thick bedded to massive greywacke and tuff or tuffaceous greywacke are characteristic of unit 2a. Siltstone and mudstone appear to be very scarce in unit 2a. In contrast unit 2b is typified by fine-grained greywacke, grey slaty mudstone and intercalated thinly bedded quartz-magnetite iron-formation. Locally the iron-formation and associated rocks have been reworked to form thin intraformational conglomerate lenses.

The northern contact of the sedimentary rocks with the volcanic rocks is apparently a fault or shear zone whereas the contact south of the map-area is gradational through intercalated tuffs, greywacke, and acid to intermediate volcanics into unit 1. The stratigraphic contact between units 1 and 2 is gradational and likely to have been time-transgressive.

These units are directly correlative with units 1 and 2 of Eade (1964, 1966).

Archean Intrusive Rocks

Hornblende diorite and biotite-hornblende tonalite comprise unit 3. Contacts of this unit with other rocks are usually sharp. However the southern contact of the pluton immediately north of the Padlei belt is an agmatite zone as much as a quarter of a mile wide.

Medium-grained, largely massive, pink quartz monzonite and granodiorite comprise unit 4. Biotite is the dominant mafic mineral. Contacts with other rocks are sharp. Inclusions and schlieren are rare. Locally these rocks are porphyritic and contain pink feldspar phenocrysts as much as one half inch long. The pluton in the northwest corner of the area has altered the bordering volcanic rocks to hornblende schists, here distinguished as unit 1c. Locally these schists and the bordering diorite are cut by irregular dykes of granitic rock similar to unit 4.

Similar quartz monzonites to the west and to the northeast give late Archean radiometric ages (R.K. Wanless, and A. Davidson, pers. comm.).

Aphebian and Aphebian (?)

Gabbro and Diabase Dykes

Coarse gabbro dykes (unit 5) cut diorite (unit 3) and volcanic rocks (unit 1) in the centre of the map-area. These dykes may be Archean in age.

Diabase dykes (unit 5a) with large plagioclase phenocrysts cut volcanic and dioritic rocks in the map-area. The structural and petrographic features of these dykes resemble those described by Davidson (1968, and in press) in the Kaminak Lake area. Preliminary radiometric age studies on the least altered of these pre-Hurwitz and post-Kenoran dykes give a whole-rock K-Ar date of 2330 ± 200 m. y. (A. Davidson, pers. comm.).

Aphebian

Montgomery Lake Sedimentary Rocks

Greenish grey, brown, and grey, pyritic, arkosic quartz arenites, siliceous siltstones, and subgreywackes are typical of this unit (6). Mildly radioactive pyritic quartz-pebble conglomerates and grits are preserved locally. In places the base of this group is marked by polymict conglomerates and subgreywacke (unit 6a) little different from those of unit 7. Ripplemarks and cross-stratification are rare.

With the exception of the northwest shore of Kinga Lake unit 6 is apparently limited to the southern flank of the Padlei synclinorium (see Fig. 2). Here and at Kinga Lake this unit underlies the Padlei Formation. On the northern flank of the synclinorium outcrop is abundant and unit 6 is apparently lacking.

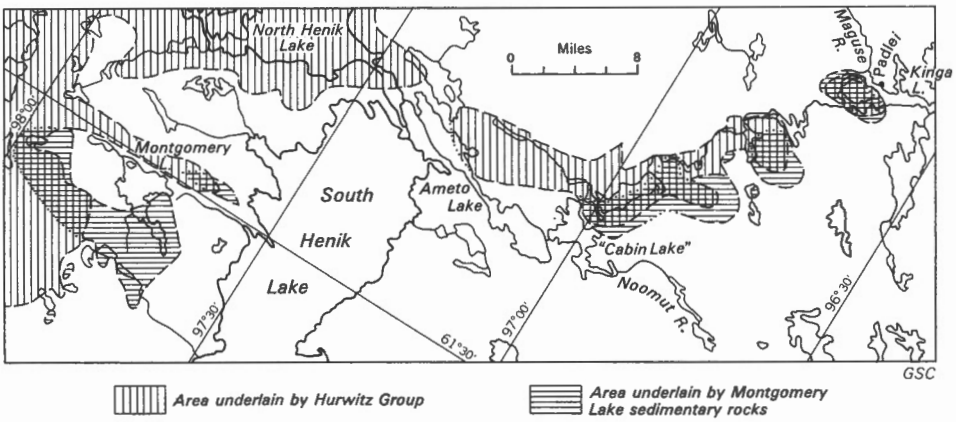

Figure 2. Distribution of Hurwitz Group and Montgomery Lake sedimentary rocks near Henik Lakes and Padlei.

It is concluded on the basis of distribution, stratigraphic position and lithologic similarities that unit 6 is correlative with sedimentary rocks near Montgomery Lake (unit 7 of Eade, 1964). Possibly unit 6 is a locally

restricted facies of the Padlei Formation and hence an integral part of the Hurwitz Group. However for the reasons stated above, and in particular because of the structural discordance observed on the north and south sides of Kinga Lake, the separation of these sediments from the Hurwitz Group and their correlation with the Montgomery Lake sedimentary rocks is strongly favoured. The unequivocal solution to this question can only be resolved by drilling the contacts of unit 6 and younger rocks. For meaningful uranium exploration in the sedimentary rocks of this general region the solution of this question is of great importance.

Hurwitz Group

In a previous publication (Bell, 1968) the Hurwitz Group (units 7-9) was informally subdivided. The present status of work permits confident definitions of some of these units as formal lithostratigraphic units and their application to the Padlei belt. All formations defined have their type sections within the map-area. Two members, for the sake of greater clarity have type areas outside the map-area, but they are adequately represented in the Padlei belt.

Padlei Formation. The name Padlei Formation (unit 7) is introduced to refer to the basal polymict conglomerates, conglomeratic mudstones and siltstones, and mudstones of the Hurwitz Group. The formation is exposed in the Padlei belt, Kognak basin and Kaminak belt (Hurwitz A and B of Bell, 1968). Except as noted below, the Padlei Formation overlies Archean volcanic, sedimentary, and intrusive rocks with marked unconformity. In the Padlei belt the Padlei Formation overlies, locally with structural discordance, rocks of unit 6. Everywhere the Padlei Formation is overlain apparently conformably by the Kinga Formation. The Padlei Formation is absent over significant areas such as the northeastern end of the Kaminak belt and in the Tavani area. A unit similar to this (unit 8a of Eade, 1966) has been recognized near Bray Lake in the Kognak basin.

The type locality is on the peninsula at the west end of Kinga Lake opposite the Hudson's Bay Company post (presently unoccupied) which served the Eskimo settlement of Padlei (abandoned). Here polymict dark grey and brownish grey polymict conglomerates and pebbly mudstones apparently overlie unconformably slightly pyritic quartz arenites of unit 6. The Padlei Formation contains thinly bedded grey slaty-cleaved laminated (varved?) mudstone and siltstone. The top of the unit is entirely composed of this latter lithology. It is overlain, apparently conformably, by the Maguse Member of the Kinga Formation. Parts of the Padlei Formation are well exposed at a lake 9 miles southwest of Kinga Lake (see Fig. 1).

Unfortunately both basal and upper contacts of the Padlei Formation are only rarely exposed. At the type locality the contacts are obscured by a covered interval about 25 feet wide. On the accompanying map (Fig. 3) basal contacts are indicated at locations A and B. Basal contacts are present near Kaminak Lake also (Bell, 1968).

Kinga Formation. The name Kinga Formation (unit 8) is introduced for the main quartz arenite unit of the Hurwitz Group - the "backbone of the Hurwitz" (Hurwitz C and D, Bell, 1968). In the Padlei belt it is present along the entire length of the synclinorium and forms distinctive ridges and abrupt

hills, such as the high hill at Kinga Lake. Appropriately "kinga" means "hill" or "mountain" in the Padleimiut Eskimo dialect (Tyrrell, 1897, p. 201F).

The greatest exposed thickness in the Padlei belt is 2,810 feet (see Appendix). To the east, in the Kaminak and Whiterock belts the thickness of the Kinga Formation (Hurwitz C and D, Bell, 1968) varies from 850 to about 1,700 feet. To the west, in the Watterson and Kognak basins the unit probably varies from slightly less than 800 to over 4,000 feet in thickness.

Maguse and Whiterock Lake Members. The Hurwitz C and D terminology is sound at least as far west as Ameto Lake and probably may be extended to the Kognak and Watterson basins as well. The upper and most widespread member, here formally designated the Whiterock Lake Member (Hurwitz D, Bell, 1968; unit 8b this report) is characterized by fine-grained, thin- to medium-bedded, ripple-marked, white, pink, and pale grey orthoquartzites. The type area for this member is at Whiterock Lake (Tavani map-area, NTS 55K). The unit is about 800 to 1,000 feet thick, and is the sole representative member of the Kinga Formation in the Tavani area.

The lower and more restricted member, here designated the Maguse Member (Hurwitz C, Bell, 1968; unit 8a this report) is characterized by medium- to coarse-grained, medium to massive bedded, white to pale grey orthoquartzites. Locally this unit is gritty and contains quartz-, quartzite-, and jasper-pebble conglomerate lenses. Ripple-marks are rarely preserved but cross-stratification is locally abundant. The Maguse Member is well exposed, albeit much deformed at the west end of Kinga Lake near the inlet of Maguse River. The Maguse Member is lacking in the Whiterock belt and very thin at the northeast end of the Kaminak belt. Its thickness increases progressively to the southwest, and probably accounts in large part for the thickening of the Kinga Formation west of the Padlei belt.

The Whiterock Lake Member (and therefore by definition the Kinga Formation) is overlain by the Ameto Formation. The sole exception to this is on Pork Peninsula (Tavani area, NTS 55K) where it appears that the Kinga Formation (Hurwitz D) and basement rocks are unconformably overlain by impure quartzites (Hurwitz G, Bell, 1968) presumed to be younger than the Ameto Formation.

Paleocurrent information in the Padlei belt (from the Whiterock Lake Member) again confirm sediment transport from the southeast (Bell, 1968).

Ameto Formation (including Happotiyik Member). The name Ameto Formation is proposed for the pelitic unit succeeding the Kinga Formation. The type locality (see Appendix) is near Ameto Lake where probably the most continuous exposure of this unit is available for study.

Eade's description (1966, p. 9) of this unit in the Kognak River area can be scarcely improved:

> "Slate, shale, and siltstone (10) overlying the orthoquartzite (9), outcrops poorly, and slaty fragments littering the ground are commonly the only evidence for the presence of this map-unit. Areas underlain by these rocks typically have a featureless local topography readily recognizable on the ground and on air photographs. The slate, shale and siltstone, are grey to black or red, fine- to very fine-grained

and have thin bedding laminations 1/16 to 1/4 inch thick. Prominent slaty cleavage so prevalent in this unit, in places obscures the bedding. Here and there in these fine-grained rocks there are lenses of well bedded, medium-grained greywacke. Near Griffin Lake, a thin dolomite horizon (11) lies immediately above the orthoquartzite (9). The dolomite is overlain by slate, shale and siltstone (10) in turn overlain by the principal dolomite and argillite (11) beds."

West of the type area the Ameto Formation is overlain by a thick unit of dolomite and siltstone (unit 11 of Eade, 1966). In the Padlei belt the Ameto Formation is the youngest exposed sedimentary unit. To the east in the Whiterock belt the Ameto Formation (Hurwitz E, Bell, 1968) is as much as 800 feet thick and is unconformably overlain by impure quartzose, lithic, and sericitic arenites (Hurwitz G). In the Kaminak belt the Ameto Formation is the youngest unit (Hurwitz E plus Hurwitz Fa, Bell, 1968) and is probably as much as 1,700 feet thick, including a thick (perhaps as much as 1,000 feet thick) volcanic sequence here formally designated the Happotiyik Member after the lake at the northeast end of the Kaminak belt (NTS 55L).

In the Padlei belt the Happotiyik Member (see Appendix) is only 86 feet thick and is presumed to wedge out to the west as it has not been observed west of Ameto Lake. The Happotiyik Member is likewise absent in the Whiterock belt.

Aphebian Intrusive Rocks

At the southwest end of the Padlei belt the Ameto Formation is cut by a thick gabbro sill here designated unit 10. Previously this unit was designated Hurwitz Fb (Bell, 1968) and because of its intimate relationship with the volcanic member interpreted as being coeval with the volcanic rocks. In the described section (see Appendix) it is plain that the sill cuts the Ameto Formation at a higher level than the volcanic member. However the unique restriction of these sills to the Ameto Formation and as dykes to older units in the area between Watterson Lake (NTS 65G) and the Whiterock belt (see Eade, 1964, 1966, Wright, 1968, Bell, 1968) still strongly suggests that the gabbro is coeval with the upper part of the Ameto Formation and more specifically with the upper part of the Happotiyik Member as expressed at Kaminak and Quartzite Lakes.

STRUCTURAL GEOLOGY

The Hurwitz Group has been intensely deformed by the Hudsonian Orogeny, generally following a northeasterly structural trend. The areas underlain by the thickest development of the Montgomery Lake sediments (unit 6) have a more easterly trend, possibly reflecting an earlier, and pre-Hurwitz but post-Archean deformational episode. On the other hand these trends (easterly) may reflect in part an inherited Archean basement trend.

The Padlei belt is dissected by a number of northerly- and northwesterly-trending faults. Three westerly to northwesterly faults in the southwest corner of the map-area show high angle reverse fault relationships and enclose a downthrown block. Geophysical evidence (Geological Survey of Canada, 1966) suggests that these faults continue as far east as Harling Lake (see Fig. 3).

ECONOMIC GEOLOGY

The most significant contribution to the studies of the Hurwitz Group was Eade's (1964) recognition of pre-Hurwitz sediments near Montgomery Lake. The author has identified similar rocks in the Padlei belt and restricted previously reported occurrences of pyritic, quartz and quartzite-pebble conglomerates to this succession, in contrast to the relatively more mature, non-pyritic, quartz-, quartzite-, and jasper-pebble conglomerate and grit lenses so common in the lower member of the Kinga Formation. Figure 2 illustrates the distribution of the Montgomery Lake sedimentary rocks and the Hurwitz Group in the Padlei belt and part of the Kognak basin.

Claims were staked in the southwest corner of the map-area and a number of drillholes penetrating unit 7 and basement rocks were drilled in 1961 by Selco. No significant gold or uranium values were encountered and subsequently these claims were allowed to lapse.

Staking in late 1968 and early 1969 has blanketed Aphebian age rocks in the Padlei belt and in the Kognak basin. Ultimately serious systematic drilling in the lower elements of the Hurwitz and Montgomery Lake sedimentary rocks should resolve their stratigraphic relationship and economic value.

Table I summarizes data concerning samples of the conglomerates from the Padlei belt. All except possibly specimen R1 are believed to be from unit 6. Heavy mineral separates from these specimens contain monazite, zircon, apatite, sphene, tourmaline, rutile, and pyrite. Magnetite, goethite, and rarely chalcopyrite and hematite are also present. Pyrite may comprise as much as 8 per cent of the rock, but usually it is between .5 to 5 per cent.

The localization of pyrite in unit 6 suggests that it may have been in part detrital and/or diagenetic. However the deformation and accompanying weak metamorphism has resulted in remobilization and recrystallization. Davidson's observations (in press) on the metamorphism of the pre-Hurwitz diabase dykes (present report unit 5a) show that the Hurwitz of the Kaminak belt lies north and consequently at higher metamorphic grade than the first appearance of stilpnomelane in these dykes. Indeed, andalusite knots are present in a few beds of the Maguse Member north of Carr Lake.

The bulk of the phenoclasts in unit 6 are quartz pebbles. Quartzite, jasper and chert clasts are readily apparent. Felsite and more rarely dioritic and granitic fragments are present locally.

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APPENDIX

Ameto Lake Section

This section is 19 miles southwest of the Hudson's Bay Company post (presently unoccupied) at Padlei. The base of the section is about 5 1/2 miles due north of the outlet of Ameto Lake. The section was measured southeasterly from base to top along a small tributary flowing into the west end of an arcuate or "stocking" shaped lake, presently unnamed. This is the type section for the Ameto and Kinga Formations of the Hurwitz Group.

Base of section: 61°43'17"N, 97°04'31"W.
Top of section: 61°43'03"N, 97°02'09"W.

Unit	Lithology	Thickness (feet) Unit	Thickness (feet) From Base
	PRECAMBRIAN		
	APHEBIAN		
	Ameto Formation		
20	Coarse-grained gabbro sill, enclosed (on strike) by slates similar to those of unit 18.	var. 0-200'	4600+
19	Covered interval, recessive.	160	4657
18	Mudstone and siltstone, medium greenish grey to dark grey; thinly bedded to massive, graded, lower 100 feet contains thin tuffaceous beds; weathers dark grey to brown, recessive; slaty cleaved.	383	4497
17	Volcanics, andesitic, fine-grained, medium grey, locally porphyritic, minor pyritic; massive, grading suggests at least three separate flows, thickest of which is 40 feet thick at base; upper 2 feet of unit 17 grades into unit 18; weathers dark grey to brown, resistant; lower contact baked; unit 17 is the Happotiyik Member of the Ameto Formation.	86	4114
16	Siltstone, mudstone, very fine sandstone, slightly pyritic, medium greenish grey; thinly bedded 1 inch to 2 inches, graded, locally may be tuffaceous; weathers brown, resistant; slaty cleaved.	38	4028

Unit	Lithology	Thickness (feet) Unit	From Base
15	Mudstone, siltstone and very fine grained sandstone, alternating medium greenish grey and light grey, minor disseminated magnetite and pyrite, locally may be tuffaceous; thinly bedded, graded; weathers greyish brown, moderately resistant; slaty cleaved.	75	3990
14	Mudstone and siltstone, slightly pyritic, alternating medium and dark grey; thinly bedded; weathers grey, recessive; slaty cleaved.	20	3915
13	Mudstone, slightly calcareous, alternating dark grey to light pinkish grey; thinly bedded, minor pink argillaceous dolomite beds as much as 12 inches thick; weathers grey, recessive.	70	3895
12	Covered interval, recessive.	40	3825
	Kinga Formation		
	(Whiterock Lake Member units 9 to 11 inclusive)		
11	Siltstone and very fine grained sandstone, primary breccia, quartzose, cherty, red; very thinly bedded, disturbed laminations, intraformational breccia, lower 5 feet with cherty red siltstone tabular fragments in a semifriable red siltstone matrix; weathers red, moderately resistant.	35	3785
10	Sandstone (orthoquartzite); very fine grained, very light grey to very light brown, white and pink; bedding 1 inch to 12 inches, ripple-marked; weathers white to pink, resistant.	465	3750
9	Sandstone (orthoquartzite), very fine grained, very light grey, white and rarely very light brown; bedding 6 to 24 inches, ripple-marked, rarely cross-stratified, weathers white to grey, pinkish near top, resistant.	525	3285

Unit	Lithology	Thickness (feet) Unit	From Base
	(Maguse Member units 3 to 8 inclusive)		
8	Sandstone (orthoquartzite), fine to coarse grained, rarely gritty, very light grey to white; bedding 2 to 3 inches in 6 to 8 foot units, locally with fine quartz and jasper-pebble conglomerate lenses; weathers grey resistant.	200	2760
7	Sandstone (orthoquartzite), fine to medium grained, very light grey to white; bedding 4 to 6 inches in 8-foot units, minor planar cross-stratification; weathers grey resistant.	155	2560
6	Sandstone (orthoquartzite), fine to medium grained, white; bedding 6 to 12 inches, rarely massive; weathers grey, resistant.	340	2405
5	Covered interval, recessive.	15	2065
4	Sandstone (orthoquartzite), minor disperse grey (specular) hematite, fine- to medium-grained, light grey to white, minor pink, bedding 2 feet to massive, minor cross-stratification, minor gritty to fine quartz-pebble conglomerate lenses; weathers grey, resistant.	700	2050
3	Sandstone (orthoquartzite) medium- to coarse-grained, abundant gritty to fine conglomeratic zones; light grey, rarely pink and light brown; bedding 2 to 4 feet thick, minor cross-stratification, rare ripple-marking; weathers grey to brown, moderately resistant to recessive. Grit and conglomeratic zones, oligomictic with about 1/2 per cent jasper pebbles and rare felsite and chert pebbles. Lower 50 feet is poorly exposed and grades downwards into gritty pinkish to brown hematitic micaceous and feldspathic sandstone and grit.	375	1350

Unit	Lithology	Thickness (feet) Unit	From Base
	Padlei Formation (?)		
2	Essentially drift covered interval with poor rubbly outcrops near the top of brownish weathering, quartzose, micaceous and feldspathic sandstone, and in the lower 100 feet several small outcrops of polymict conglomerate having a matrix of green micaceous and quartzose siltstone with volcanic (largely felsite), slate and minor quartz pebbles, generally with and intact framework. Thickness of this unit estimated assuming 45 degree dip of rocks in unit 3 although poor layering in the conglomerates suggest that the dip near the base of this interval is only 26 degrees.	975	975
	ARCHEAN		
	Kaminak Group (volcanic facies)		
1	Felsites, pale greenish grey, porphyritic, locally brecciated; unit dipping about 45 degrees southeasterly, tops not determined.		
	Base of measured section at top of unit 1.		

Table I: Data Concerning Selected Pyritic Quartz - Pebble Conglomerates of Padlei Belt

Location (see map)	Scintillometer Reading μR/hr. (on outcrop) (1)	U, Th, K content determined by γ-ray Spectroscopy (2)			U content determined by hot nitric acid leach (3)	
		%K	ppm Th	ppm U	Specimen Ground to 100 mesh ppm	Specimen Ground to 250 mesh ppm
Ra*	19	–	–	–	–	–
Rb	15	–	–	–	–	–
Rc	20	–	–	–	–	–
Rd	15	2.1	5.3	11.4	2	3
Re(specimen I)	65	8.2	26.8	67.0	5	7
Re(specimen II)	65	4.4	27.8	31.8	3	7
Rf*	55	1.5	62.8	9.0	8	10
Rg	5	–	–	–	–	–
Rh	15	–	–	–	–	–
Ri	18	1.3	12.5	3.7	3	4
Rj*	30	2.1	25.7	5.1	2	3
Rk	6	–	–	–	–	–
Rl*	15	2.4	16.4	6.1	2	4
Rm	6	–	–	–	–	–

* rubble, frost heaved blocks, probably not transported.
(1) Model: Ratemeter type NE 148 A (Rank Nucleonics).
(2) Determined by A.G. Darnley & R. Grasty, Geol. Surv. Can., following method outlined by Adams (1964).
(3) Determined by J.J. Lynch of Geol. Surv. Can., following method outlined by Smith and Lynch (1969).