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Constraints on the age of the Klinkit assemblage east of Teslin Lake, northern British Columbia1

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Abstract: Volcaniclastic and overlying dark sedimentary rocks of the Klinkit assemblage (NTS 104-O/11) are the youngest of several arc remnants that lie between the Cassiar Platform and Cache Creek terrane in the British Columbia–Yukon border area. New U-Pb geochronological and micropaleontological data indicate Late Carboniferous (or younger) to Late Triassic age for the assemblage.

Limestone at the base of the Klinkit assemblage contains Bashkirian conodonts. Intrusive rocks, more deformed than the Klinkit assemblage, are ca. 340 Ma and ca. 320 Ma. A tuff, probably correlative with the Klinkit assemblage, yielded an Early Permian (ca. 281 Ma) date. Middle to Late Triassic conodonts were recovered from the argillaceous upper unit. We conclude that Klinkit volcanism, begun in the Late Carboniferous, continued through Permian time and was followed by Triassic clastic sedimentation.

Correlative late Paleozoic volcanic centres and Triassic sedimentary rocks in the pericratonic belt are found in central Yukon and north-central British Columbia.

Résumé : L'assemblage de Klinkit (SNRC 104-O/11), qui se compose de roches volcanoclastiques surmontées de roches sédimentaires de couleur sombre, forme le plus récent d'une suite de vestiges d'arc intercalés entre la plate-forme de Cassiar et le terrane de Cache Creek, près de la limite entre le Territoire du Yukon et la Colombie-Britannique. De récentes données micropaléontologiques et géochronologiques (U-Pb) indiquent que cet assemblage s'échelonne du Carbonifère tardif (ou avant) au Trias moyen.

À la base de l'assemblage de Klinkit, un calcaire renferme des conodontes du Bashkirien. Des roches intrusives, plus déformées que celles de l'assemblage de Klinkit, ont livré des âges d'environ 340 Ma et 320 Ma. Un tuf, probablement corrélatif de l'assemblage de Klinkit, a été daté du Permien précoce (env. 281 Ma). Des conodontes du Trias moyen et tardif ont été prélevés dans l'unité argileuse supérieure. On en déduit que le volcanisme de Klinkit a commencé au Carbonifère tardif et s'est poursuivi tout au long du Permien et qu'une sédimentation clastique a pris le relais au Trias.

Des centres volcaniques du Paléozoïque tardif et des roches sédimentaires du Trias avec lesquels peuvent être établies des corrélations sont présents à l'intérieur de la ceinture péricratonique dans le centre du Territoire duYukon et le centre nord de la Colombie-Britannique.

[1] Contribution to the Ancient Pacific Margin NATMAP Project.

INTRODUCTION

Among the great challenges in the northern Canadian Cordillera are the mapping and interpretation of deformed volcanic and sedimentary rock units that lie between the North American miogeocline and 'outboard terranes' (including Stikinia, Wrangellia; *see* Monger et al., 1991) (Fig. 1). Referred to here as the 'pericratonic belt', these rocks have been difficult to resolve because they include polydeformed arc successions which overlap in time and space. Some of these rock assemblages have been mapped, their ages determined, and regional paleogeographic reconstructions begun within the Ancient Pacific Margins NATMAP project.

Within the pericratonic belt in northern British Columbia, the Klinkit assemblage lies east of the Big Salmon complex (characterized by Late Devonian and Mississippian magmatic rocks; Mihalynuk et al., 1998, 2000), and west of the Swift River succession (an undated clastic unit older than Late Carboniferous; Nelson, 2001; Fig. 2). The base of the Klinkit assemblage (Harms et al., 1997) is a regional carbonate unit (Screw Creek limestone) which stratigraphically overlies the Swift River succession (Fig. 2). The Klinkit assemblage is divided into three units which are mappable over a 30 km by 8 km area.

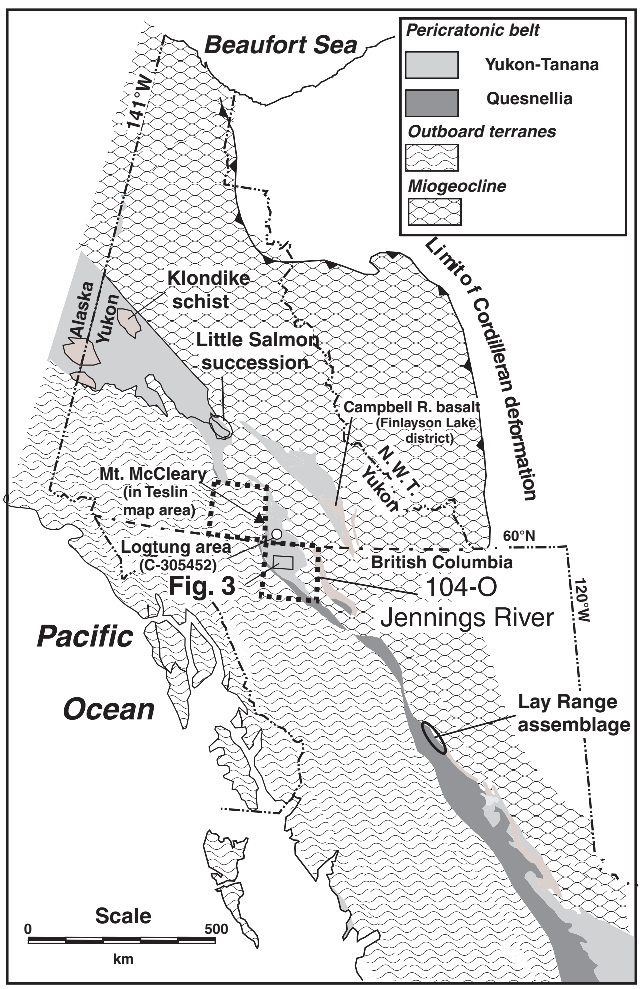

Figure 1. Belt of pericratonic rock assemblages (shaded) in northern British Columbia and south Yukon showing areas mentioned in text.

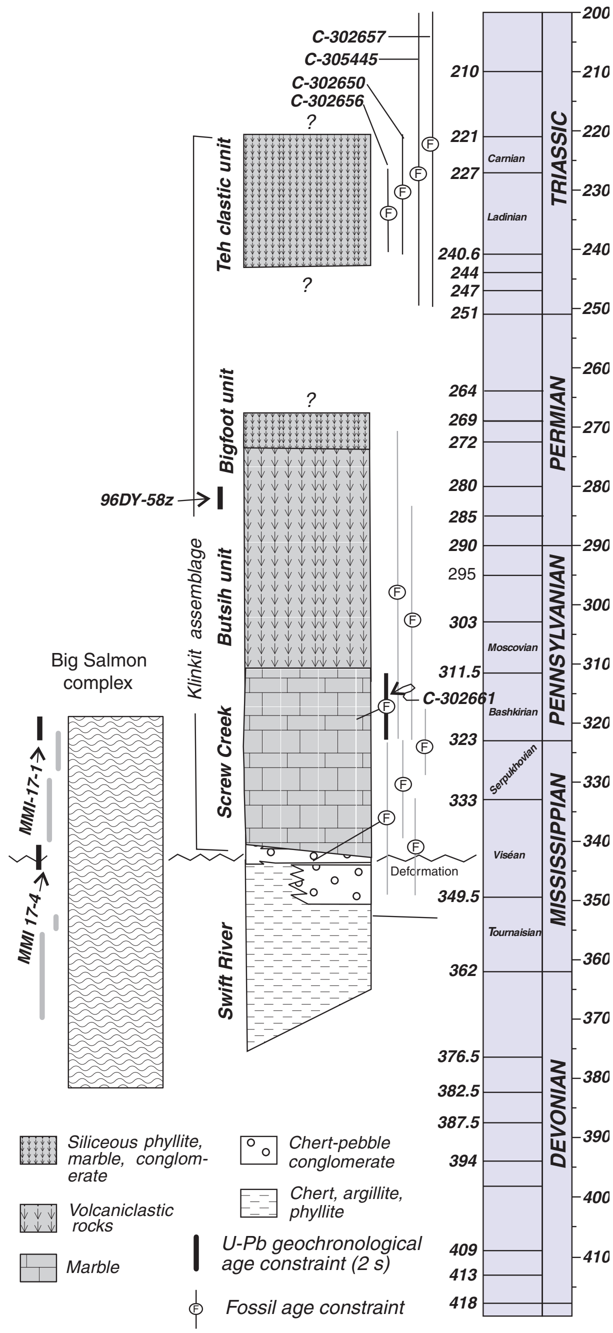

Figure 2. General stratigraphy and age constraints for northwestern and central Jennings River map area. Dark bars represent samples recorded in this report; shaded bars and time scale are as presented in Colpron and the Yukon–Tanana Working Group (2001).

The age of the Klinkit assemblage distinguishes it from the compositionally similar Big Salmon complex. In this paper we present new U-Pb and conodont ages which help to date this unit in which datable rocks are rare and some contact relationships are obscure.

REGIONAL GEOLOGICAL UNITS

The Klinkit Lake map area (NTS 104-O/11) has been the focus of geological mapping and study of volcanic facies and geochemical compositions (e.g. Harms, 2001; Simard et al., 2001). The northern third of the map area is underlain by (north to south on Fig. 3) the Early Jurassic Simpson Peak batholith; a belt of dark metasedimentary and volcanic rocks of the Swift River succession and Klinkit assemblage; and the Klinkit batholith of probable Cretaceous age. The Swift River succession is dominantly dark-coloured chert and argillite interspersed with quartzite-phyllite sequences, quartz wacke, quartzite, and local pebble conglomerate (Nelson, 2001). It is overlain by the Screw Creek limestone, a prominent light-coloured reef and debris-flow carbonate. The upper part of the Klinkit assemblage is divided into three units, the Butsih, Bigfoot, and Teh. The Butsih unit consists of predominantly volcaniclastic and volcanic epiclastic layers and rare aphanitic flows. The middle Bigfoot unit (transitional unit of Mihalynuk et al., 2000; Harms, 2001) contains cherty volcaniclastic tuff and carbonate rocks with lesser amounts of dark grit and siltstone. The uppermost Teh unit is characterized by interbedded black argillite, dark siltstone, sandstone and chert, with minor limestone and pebble conglomerate.

The Klinkit assemblage is folded at all scales and is of upper greenschist to lower amphibolite metamorphic grade.

West of NTS 104-O/11 is Teh Creek map area (NTS 104-O/12; Mihalynuk et al., 2001), which is largely underlain by the Big Salmon complex and Jurassic and Cretaceous intrusions. The eastern edge of NTS 104-O/12 is underlain extensively by volcanic rocks of both the Big Salmon complex and Klinkit assemblage, but the contacts are not exposed. This area contains the three units of the Klinkit assemblage and the best exposures of the lowest Butsih volcanic rocks. Four of the five samples for isotopic dating were collected in this area.

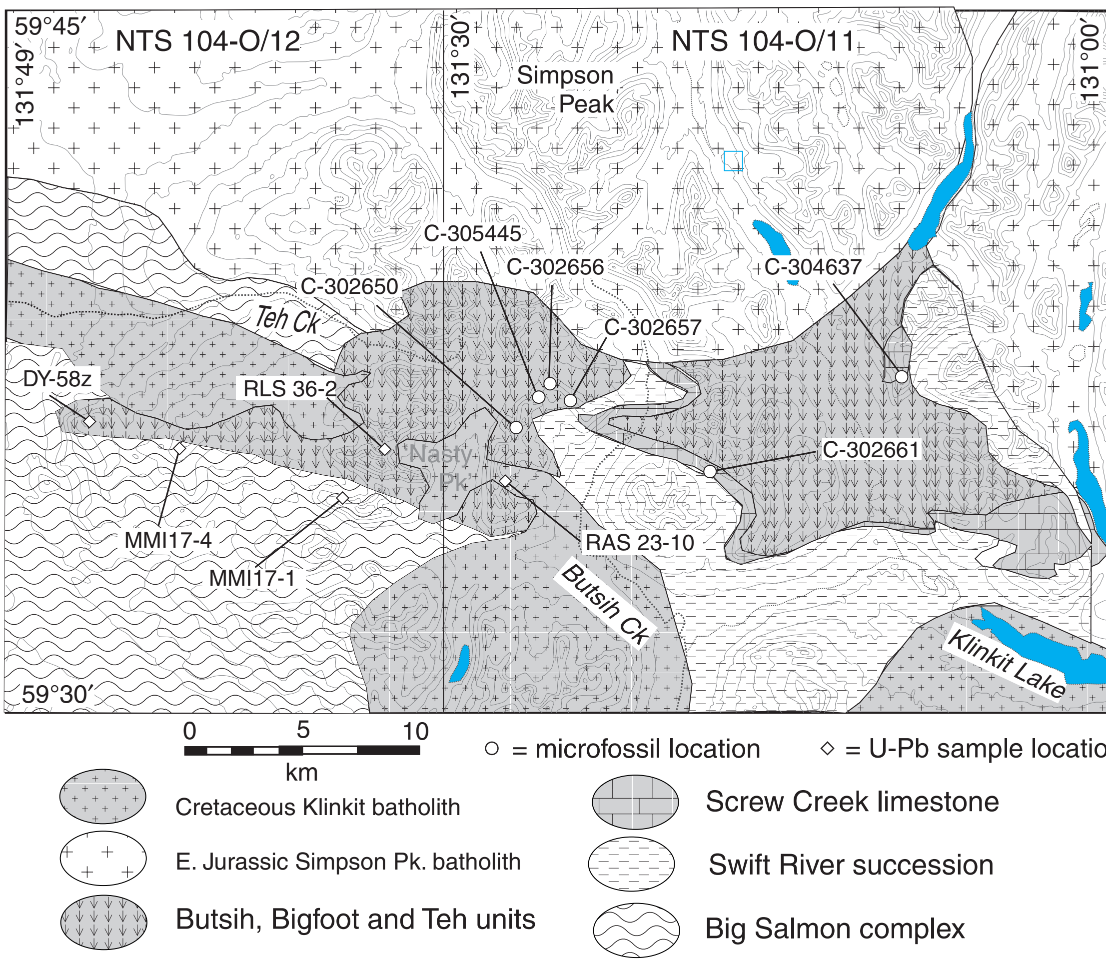

Figure 3. *Location of samples for age determination in NTS 104-O/11 and NTS 104-O/12 (east half) map areas. The distribution of major geological units is taken from Mihalynuk et al. (2000) and T. Harms (unpubl. data). Contour interval is 100 m.*

AGE DETERMINATIONS

Paleozoic and Mesozoic faunal collections, and five U-Pb isotopic ages for zircon are reported in this section. For each, the geographic and geological setting is described first, and a discussion of the significance to the age of the Klinkit assemblage follows.

Paleontology

Screw Creek limestone

Light-beige-weathering, thick, and poorly bedded limestone forms a topographic bench at the sampled locality near the middle of the studied map area NTS 104-O/11. Along its 8 km strike length it is underlain by quartzite correlated with the Swift River succession to the southwest, and overlain by Butsih volcanic rocks to northeast.

At the sampled locality the limestone contains abundant macrofossil debris, including bryophyte and horn-coral fragments, rare brachiopods, and an uncoiled nautiloid. Beds of colonial corals were noted in two places. Almost everywhere the remains are silicified and the lack of preserved fine details precludes identification to the Genus level. Only one of more than eight collections contained microfossils (C-302661; Table 1). *Declinognathodus* sp. conodonts in this sample indicates a Bashkirian (Late Carboniferous) or slightly younger age.

The Carboniferous age is within the range of ages determined for the Screw Creek limestone (e.g. Abbott, 1981; Nelson et al., 2001), which is regionally overlain by mafic to intermediate volcanogenic rocks. In eastern Teslin map area, about 5 km north of Mount McCleary, a 40 m thick lens of limestone containing Serpukovian conodonts is entirely enclosed by quartz-rich clastic rocks (Gordey, 1997; collection C-300502 in GSC Paleontological database).

This date and the clear stratigraphic succession definitively indicate that the Klinkit assemblage in Klinkit Lake map area is Bashkirian and younger.

Teh clastic unit

Dark siltstone and argillite interbeds characteristic of this unit are best exposed on a north-trending ridge near the west side of Klinkit Lake map area. The basal contact of the unit changes from an angular unconformity above the Bigfoot and Butsih units in eastern NTS 104-O/12, to a seemingly gradational contact in western NTS 104-O/11 map area, to an unconformity directly above the Screw Creek limestone and the Swift River succession in eastern 104-O/11. The Teh unit contains single beds of dark grey, silty limestone commonly less than 30 cm thick. Four out of seven collections from this unit contained conodonts (Table 1; although some of these may be structural repetitions of the same bed). The Middle to Late Triassic age is determined by presence of *Neogondolella*, which, in one case, can be identified to the species level. Although the clastic unit clearly includes rocks of Middle to Late Triassic age, the full age range is unknown because of the extent of underlying undated strata and lack of an overlying unit.

Triassic rocks in the pericratonic belt include synorogenic clastic rocks (Tempelman-Kluit, 1979; cf. Gordey and Makepeace, 2001, unit Trs) and shaley limestone (Abbott, 1983). The unit represents a previously unrecognized lithological unit in the pericratonic belt. Its regional significance is demonstrated by the recent recovery of similar Triassic conodonts in black argillaceous siltstone in southern Yukon, about 4 km northwest of the Logtung deposit (Abbott, 1981). This occurrence (C-305452; Table 1) is located 52 km north of the Klinkit occurrences described here and additional undated black clastic rocks have been mapped even farther to the northwest.

Zircon U-Pb geochronology

Here we report U-Pb dates for zircon from samples of quartz diorite, gabbro, tuff, andesite sill, and granite. At the University of Alberta Radiogenic Isotope Facility the standard crushing, mineral separation, and analytical techniques were employed as described in Roots and Heaman (2001). The rock type, location, and description of analyzed zircon fractions are presented in Table 2. Results of U-Pb analyses of these fractions are given in Table 3 and on concordia diagrams (Fig. 4 to 8).

Table 1. Location and fauna in productive collections from Klinkit assemblage carbonates. Data taken from GSC Paleontological reports: MJO-1997-7 (for C-302650, -302656, -302657, and -302661), MJO-2000-4 (for C-304637), for MJO-2001-5 (for C-305445 and -305452).

GSC_Loc	Collector	Field #	*Genus*	Species	NTS	UTM*E	UTM*N	System_Age	Series	CAI_Min
C-302661	T.A. Harms	94-DY-132i	*Declinognathodus*	sp.	104-O/11	369625	6607825	Late Carboniferous	Bashkirian	5
C-304637	C.F. Roots	99-RAS-23-03	ramiform elements	indet.	104-O/11	378500	6611650	Ordovician to Triassic		6
C-302657	T.A. Harms	94-DY-76	*Neogondolella*	sp. indet.	104-O/11	364350	6610660	Triassic?		5
C-302656	T.A. Harms	94-DY-72A	*Neogondolella*	ex gr. *constricta*	104-O/11	362700	6610425	Middle Triassic	?Ladinian	5-6
C-305445	C.F. Roots	00-RAS-15-4	*Neogondolella*	sp. indet.	104-O/11	362450	6610450	Triassic		5
C-302650	T.A. Harms	95-DY-93	*Neogondolella?*	sp. indet.	104-O/11	362050	6609110	Middle-Late Triassic	Lad.-Carn.	5
C-305452	C.F. Roots	00-RAS-23-2	*Metapolygnathus*	*polygnathiformis*	105 B/4	353378	6658552	Late Triassic	Carnian	5-6

* Universal Transverse Mercator (UTM) grid is Zone 9, North American Datum 1927

Table 2. Description of zircon fractions and location information for igneous samples in Table 3.

Sample lithology and location	Fraction	Description of zircon fraction
MMI99-17-4 ***Quartz diorite (Big Salmon complex?)***		
Medium-grained, light-weathering felsic meta-intrusive; foliated and silicified.	1	17 large rugged yellow-white or transparent subhedral prisms & fragments (2:1 length:width); with inclusions; magnetic fraction at 1° tilt
Collected 8 km east-southeast of Teh Creek mouth.	2	20 equant prisms: colourless, subhedral, slightly resorbed; magnetic fraction at 1° tilt
UTM zone 9 346998E 6608593N		
East half of NTS 104-O/12 map area		
MMI99-17-1 ***Pegmatitic gabbro (Big Salmon complex?)***		
Pegmatitic gabbroic phase of intrusion complex.	1	1 resorbed prism (2:1) colourless methylene-iodide heavy fraction
Collected north face of '1865 m Peak' 16 km east-southeast of mouth of Teh Creek. UTM zone 9 355695E 6606164N	2	1 broken needle faint tan euhedral methylene-iodide heavy fraction
East half of NTS 104-O/12 map area		
96DY-58Z ***Andesite tuff (Butsih volcanic unit, Klinkit assemblage)***		
Fine-grained, massive green tuff collected at top of north-	1	1 medium-sized, slightly frosty, colourless fragment; methylene-iodide heavy fraction
facing cliff section 5 km east of mouth of Teh Creek (104-O/12). UTM zone 9 344350E 6609925N	2	1 medium sized, slightly frosty, colourless prism fragment; methylene-iodide heavy fraction
East half of NTS 104-O/12 map area	3	4 small prisms and tips, with small fluid inclusions; methylene-iodide heavy fraction
99-RAS-23-10 ***Granite*** *(outlier of Klinkit batholith?)*		
Medium-grained biotite-hornblende granite	1	23 smallest euhedral prisms, length:width 2:1; magnetic fraction at 15° tilt
Collected on spur south of tarn 3 km west of Butsih Creek.	2	12 tan, euhedral prisms, abundant fractures; length:width 2:1
UTM zone 9 35360965E 6607125N; elevation 1560 m; NTS 104-O/11 map area.	3	7 faint-tan to colourless needles, euhedral to slightly resorbed, with inclusions; non-magnetic fraction at 1° tilt
	4	21 faint-tan to colourless, euhedral prisms, length:width 2:1; non-magnetic fraction at 1° tilt
2000RLS-36-2 ***Andesite sill (within Klinkit assemblage)***		
2.5 m thick grey andesitic sill with abundant hornblende and	1	1 larger resorbed, colourless, prism tip with inclusions; non-magnetic fraction at 5° tilt
mafic phenocrysts. Collected in saddle 400 m N of prom. peak. UTM zone 9 356650E 6608325N elev 1710 m	2	12 best least-altered small prisms with fractured tips and rods; prisms have black coating and inclusions
East half of NTS 104-O/12 map area	3	40 poor, very tiny, milky white, fractured prisms with excessive black coatings
Universal Transverse Mercator (UTM) grid is North American Datum 1927		

Quartz diorite

Sample MMI99-17-4 is a sample of well foliated, medium-grained quartz diorite collected from an area of discontinuous outcrop where greenstone of the Big Salmon complex and andesitic volcanic rock of the Klinkit assemblage appear to be in contact. Adjacent to the locality, to the north and west are isolated outcrops of quartz-rich sandstone, siltstone, and limestone, but their contacts and those of the quartz diorite are covered. Silicification and chloritization of mafic minerals are widespread, and this entire area is interpreted to be underlain at shallow depth by the Simpson Peak granite.

Two zircon populations were identified and analyzed. Most of the zircon crystals consist of prisms or fragments ranging in size and proportion from almost equant to prismatic (2:1 length to width). The main zircon population consists of generally clear, yellow to colourless grains showing some resorption and containing mineral inclusions. A smaller population of small broken needles was present in the least magnetic fraction.

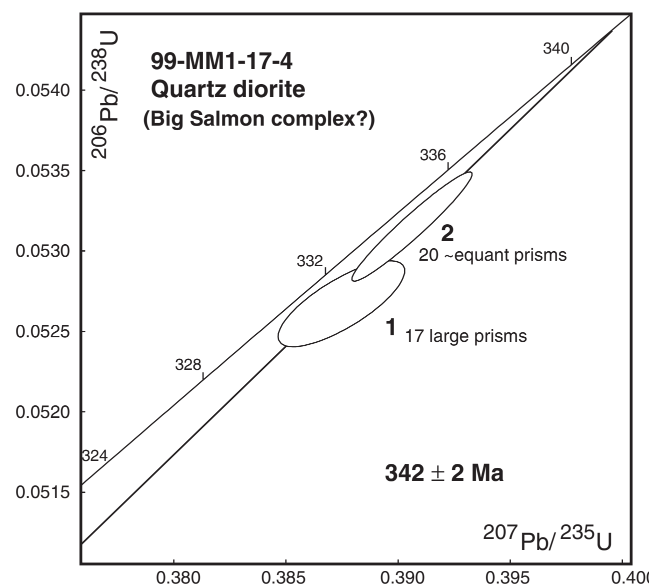

Figure 4. *Concordia plot with 2-sigma error estimates for two zircon fractions from foliated quartz diorite.*

Table 3. Uranium-lead analytical data for five samples from northern Jennings River map area, northern British Columbia.

Zircon fraction	Concentration (ppm)						Atomic Ratios (± 1 sigma error)				Model Ages (Ma ± 1 sigma error)			Per cent discordance
	Weight (mg)	U (ppm)	Th (ppm)	Pb (ppm)	Th/U[a]	Pb[b] (pg)	$^{206}Pb/^{204}Pb$[c]	$^{206}Pb/^{238}U$[d]	$^{207}Pb/^{235}U$	$^{207}Pb/^{206}Pb$	$^{206}Pb/^{238}U$	$^{207}Pb/^{235}U$	$^{207}Pb/^{206}Pb$	
MMI99-17-4 **Quartz Diorite** (Big Salmon complex?)														
1	93	214	12	80	0.38	80	923	0.05267 ± 11	0.3875 ± 12	0.05335 ± 11	330.9 ± 0.7	332.5 ± 0.8	343.9 ± 4.3	3.9
2	59	356	19	139	0.39	15	4753	0.05315 ± 1	0.3906 ± 11	0.05330 ± 4	333.8 ± 0.9	334.8 ± 0.8	341.7 ± 1.7	2.4
MMI99-17-1 **Pegmatitic Gabbro** (Big Salmon complex?)														
1	3	104	18	53	0.51	6	439	0.14676 ± 11	1.4226 ± 132	0.07030 ± 39	882.8 ± 6.0	898.5 ± 5.5	937.2 ± 11.4	6.2
2	3	52	3	52	1.03	3	374	0.05128 ± 32	0.3336 ± 178	0.04718 ± 242	322.4 ± 2.0	292.3 ± 13.5	58.6 ± 100.0	-
96DY-58Z **Andesite Tuff** (Butsih unit, Klinkit assemblage)														
1	9	72	35	5	0.48	16	123	0.04464 ± 12	0.3154 ± 64	0.01523 ± 100	281.6 ± 0.7	278.3 ± 4.9	251.2 ± 44.3	-12.3
2	10	80	36	4	0.45	3	655	0.04448 ± 9	0.3104 ± 29	0.05062 ± 44	280.5 ± 0.5	274.5 ± 2.2	223.4 ± 20.0	-26.1
3	15	55	33	4	0.60	16	162	0.04472 ± 10	0.3135 ± 47	0.05084 ± 73	282.0 ± 0.6	276.9 ± 3.6	233.7 ± 32.6	-21.1
99-RAS-23-10 **Granite** (outlier of Klinkit batholith?)														
1	8	2125	38	915	0.43	5	3931	0.01712 ± 4	0.1143 ± 3	0.04844 ± 6	109.4 ± 0.2	109.9 ± 0.3	121.0 ± 3.1	9.6
2	13	2109	85	1189	0.56	626	62	0.01631 ± 8	0.1071 ± 43	0.04761 ± 189	104.3 ± 0.5	103.3 ± 3.9	80.2 ± 91.5	-30.3
3	3	1121	28	404	0.36	25	143	0.01691 ± 5	0.1151 ± 20	0.04935 ± 80	108.1 ± 0.3	110.6 ± 1.8	164.4 ± 37.6	34.5
4	4	1819	49	777	0.43	59	140	0.01750 ± 5	0.1163 ± 17	0.04822 ± 70	111.8 ± 0.3	111.7 ± 1.6	109.9 ± 33.7	-1.8
2000RLS-36-2 **Andesite sill** (within Klinkit assemblage)														
1	2	166	127	8	0.76	11	50	0.01809 ± 11	0.1132 ± 85	0.04536 ± 334	115.6 ± 0.7	108.8 ± 7.7	-	-
2	1	1014	1860	30	1.84	8	200	0.01745 ± 4	0.1172 ± 20	0.04869 ± 78	111.6 ± 0.2	112.5 ± 1.8	133.1 ± 37.0	16.3
3	5	1312	2591	34	1.98	8	938	0.01721 ± 3	0.1146 ± 5	0.04827 ± 16	110.0 ± 0.2	110.1 ± 0.4	112.3 ± 7.7	2.0

All errors in this table are reported at 1 sigma.
Uranium decay constants used are those of Jaffey et al. (1971): $^{238}U = 1.55125 \times 10^{-10} year^{-1}$; $^{235}U = 9.8485 \times 10^{-10} year^{-1}$ and $^{238}U/^{235}U = 137.88$.
Isotopic composition of common Pb in excess of blank calculated using the two-stage average crustal Pb model of Stacey and Kramers (1975).
[a] Th calculated from ^{208}Pb abundance and U-Pb age, and assumes all ^{208}Pb derived from ^{232}Th decay.
[b] Total common Pb in analysis.
[c] Corrected for spike and fractionation.
[d] Corrected for spike, blank and fractionation.

The U-Pb results for small multi-grain fractions 1 and 2 (17 and 20 grains, respectively) are shown in Figure 4. Both fractions yielded $^{207}Pb/^{206}Pb$ ages that are very similar (344 and 342 Ma, respectively) and a weighted mean $^{207}Pb/^{206}Pb$ age of 342 ±2 Ma (MSWD=0.22) is considered the best estimate for the emplacement age of this sample.

This date is mid-Mississippian (Viséan). Although some fossil dates for Screw Creek limestone are as old as this, the nearest carbonate locality (described previously) is younger. The quartz diorite may therefore correlate with the greenstone unit in the Big Salmon complex (based upon age interpretations in Mihalynuk et al., 1998, 2000). If this intrusion is a feeder to the Big Salmon complex, this unit lies partly eroded beneath the northwestern extent of the Klinkit assemblage.

Pegmatitic gabbro

Sample MMI99 17-1 was collected from the coarsest pegmatitic phase of the texturally heterogeneous gabbro in a gabbro-basalt intrusive complex that can be traced about 13 km near the southwest edge of the NTS 104-O/11 map area and south of the Klinkit assemblage outcrop belt (Mihalynuk et al., 2000). The sampled unit contains megacrysts of plagioclase and hornblende as well as xenoliths of basalt; it is also intruded by basaltic dykes.

The poor zircon yield from this sample included about 10 zircon grains which varied from resorbed to euhedral and were mostly small prisms (1.5:1 length:width) with a few broken pieces of longer prisms (3:1 or greater). Most were clear and colourless to faint tan. Possible allanite and titanite were also recovered.

The low yield and small size of the zircons recovered made a precise age determination of this sample difficult. The U-Pb results for two single-grain analyses are presented in Figure 5. The first single zircon grain analyzed (#1) showed evidence of resorption and has a $^{207}Pb/^{206}Pb$ age of 937 Ma, likely because of xenocrystic zircon. The younger single-grain fraction (#2) shows slight reverse discordance so the $^{207}Pb/^{206}Pb$ age is geologically meaningless. However, the $^{206}Pb/^{238}U$ age of 322 Ma is likely close to the crystallization age of this grain. The high Th/U ratio of 1.0 suggests this zircon is either primary or was crystallized directly from the gabbro, or was winnowed from a mafic host because typical felsic rocks have a Th/U ratios of 0.5. Assuming this zircon grain is also a xenocryst then the 322 Ma date provides a maximum age for the volcanic unit. The remaining zircons are too low in Pb concentration to obtain a precise analysis or likely contain inherited (resorbed) grains.

This sample provides only a crude constraint on the age of the basalt-gabbro complex (Mihalynuk et al., 2000; Simard et al., 2001) as late Mississippian or Early Pennsylvanian. This unit is correlated with the Big Salmon complex because it is contemporaneous with felsic flows about 30 km further north (Mihalynuk et al., 2000) and older than the Screw Creek limestone in the area.

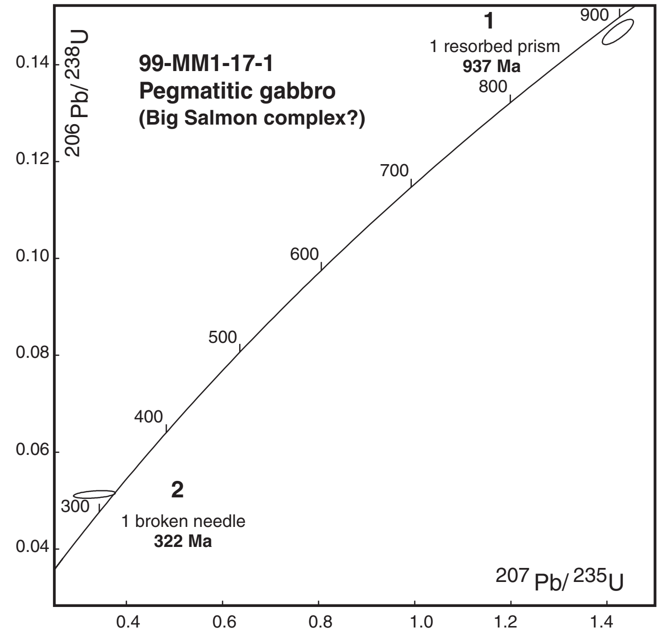

***Figure 5**. Concordia plot with 2-sigma error estimates for two zircon grains from pegmatitic gabbro.*

Andesitic tuff

The Butsih volcanic rocks have remained undated until now because felsic phases have not been found. Sample 96-DY-58z comes from the top of a sequence of volcaniclastic layers at least 150 m thick at the westernmost occurrence of the Klinkit assemblage. During reconnaissance mapping of this locality Gabrielse (1969) noted the relative freshness of this succession and mapped it separately, suggesting a correlation with the Early Triassic Shonektaw Formation whose major outcrop belt is 25 km southeast (across a major southeast-trending valley). The Shonektaw is considered the regional representative of Quesnel terrane (Monger et al., 1991).

The sample was collected from a massive, indurated, aphanitic, green, fine-grained meta-tuff with small (1 mm) amphibole phenocrysts, typical of rocks in the Butsih unit. The sample yielded a moderate amount of colourless zircon. Colourless, subhedral, prismatic zircon is most common, along with a significant number of irregularly fractured fragments. A few grains contain mineral and fluid inclusions. There is no visible evidence for cores or overgrowths and no indication that these zircon crystals could be of metamorphic origin. Two yellow zircon-like grains were also noted.

Two of these fractions (#1, 2) are single colourless fragments. Fraction #3 consisted of 4 prisms and parts of prisms containing small fluid inclusions. The uranium content of all three fractions is moderately low (55–80 ppm); this resulted in relatively horizontal error ellipses on the concordia plot (Fig. 6). The Th/U is consistently <1 (i.e. 0.45–0.60), which is typical of (but not unique to) zircon crystallizing from felsic magmas. The $^{206}Pb/^{238}U$ ages are very similar (281.6, 280.5,

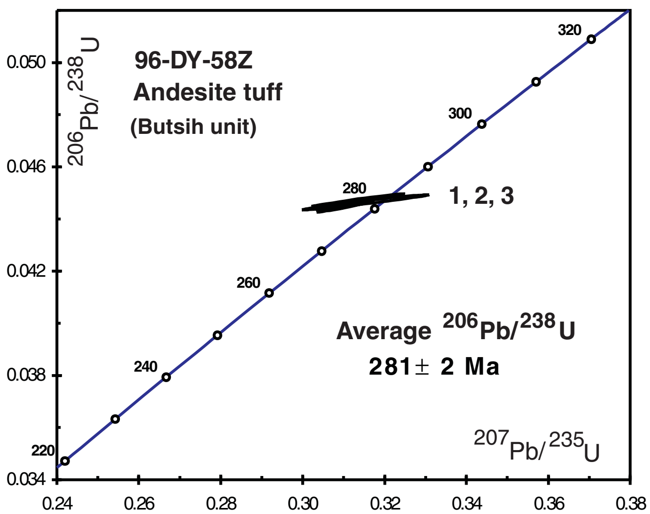

Figure 6. Concordia plot with 2-sigma error estimates for three zircon fractions from andesitic tuff.

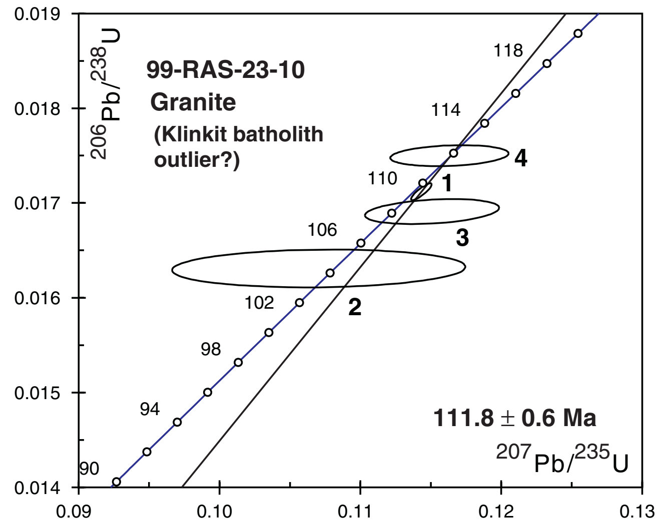

Figure 7. Concordia plot with 2-sigma error estimates for four zircon fractions for granite.

282.0 Ma) and the weighted average $^{206}Pb/^{238}U$ age of 281 ± 2 Ma is interpreted to be the best estimate for the age of the zircon.

The age is the only clear evidence that Klinkit volcanism occurred in Permian time. Although this locality is along structural trend, it is isolated from the main belt of the Klinkit assemblage by a covered interval and appears relatively fresher than most exposures of the Butsih unit. We cannot discount the possibility that it represents a younger, previously unrecognized unit. However, the rare-earth element analyses of samples collected throughout this locality compare closely with those of Butsih volcanic unit exposed at 'Nasty Peak', 12 km to the east. (R-L. Simard, unpub. data, 2001).

Granite (Klinkit batholith?)

Sample 99RAS23-10 was collected from the 2 km wide exposure of leucocratic granite in central NTS 104-O/11 map area. It is plain that the present exposure is very close to the top of the intrusion; metamorphosed volcanic rocks of the Klinkit assemblage occur along the south-dipping contact.

The medium-grained biotite-hornblende granite yielded abundant zircon. Two populations were identified: tan euhedral prisms (2:1 length to width) of various sizes and a smaller population of slightly resorbed, faint tan broken needles with inclusions.

The four fractions analyzed have quite high uranium concentrations (1121–2125 ppm) and three have quite similar $^{206}Pb/^{238}U$ ages of 108.1 to 111.8 Ma. Fraction #4 is concordant and its $^{206}Pb/^{238}U$ age of 111.8 ± 0.6 (2 sigma) Ma is considered the best estimate for the zircon age (Fig. 7).

The Cretaceous age of this stock is consistent with the age of the Klinkit batholith inferred by Gabrielse (1969). The two bodies differ in the absence of hornblende and the presence of foliated margins and mylonitic texture in the Klinkit batholith.

Andesite sill

Sample RLS-36-2 is from a 2.5 m thick massive, grey, tabular, hornblende- and plagioclase-bearing sill within contact-metamorphosed fine-grained tuff-breccia beds of the Butsih volcanic unit, about 150 m below the top of 'Nasty Peak', at the eastern edge of Teh Creek map area. The sample was analyzed to determine if it (and many prominent light-coloured intrusions in ridges to the north) is related to Early Jurassic or Cretaceous plutonism, or part of the Butsih volcanic rocks.

Among abundant pyrite and a few molybdenite grains in the least magnetic mineral fraction were a few zircon prisms (<50 microns), which were tiny, subhedral, slightly turbid, and colourless. Their small size is consistent with rapid crystallization from a flow or sill. The few (<10) larger, colourless, highly resorbed zircon grains are likely xenocrysts.

Three zircon fractions were selected. One fraction (#1) consisted of a larger single grain (likely a xenocryst), which contained the lowest uranium content (166 ppm), lowest Th/U (0.76), and oldest $^{206}Pb/^{238}U$ age of 116 Ma. The two multigrain fractions (12 and 40 crystals, respectively) consisted of prisms of generally poor quality. The crystals in fraction #3 were turbid with a milky white appearance. Both fractions #2 and #3 had high uranium contents (1014 and 1312 ppm) and high Th/U (1.84 and 1.98), typical of zircon

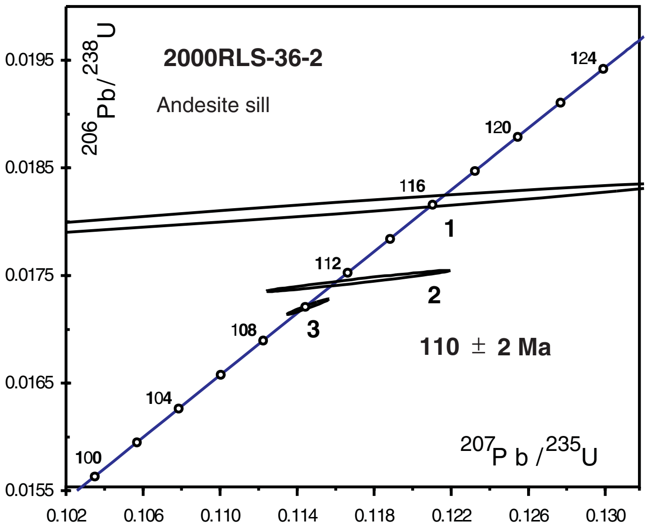

***Figure 8**. Concordia plot with 2-sigma error estimates for three zircon fractions from an andesite sill.*

crystallizing from a mafic magma. These crystals are therefore interpreted to be primary magmatic zircon. The two fractions yielded similar ^{206}Pb/^{238}U ages of 111.6 and 110.0 Ma, but plot in slightly different positions on the concordia diagram (Fig. 8). The more precise analysis is for fraction #3 and its ^{206}Pb/^{238}U age of 110 ±2 (2 sigma) Ma is considered the best estimate for the crystallization age of the zircon. It should be noted, however, that this fraction contained the poorest quality zircon and some amount of Pb-loss cannot be discounted.

The age confirms the intrusive nature of this unit and it is likely that the numerous hornblende-phyric intrusions in the western part of the Klinkit assemblage are of Cretaceous, rather than Early Jurassic or Paleozoic age.

Summary of age indications for Klinkit assemblage

Fossil identification and isotopic ages indicate that the Klinkit assemblage is no older than earliest Pennsylvanian at its base, includes Permian volcanic rocks and a record of sedimentation into Middle or Late Triassic time. We can only speculate when volcanism ended, but the nature of typical volcanic arcs is episodic. The lengthy (90 Ma) span between the earliest possible Butsih volcanism and Teh deposition is noteworthy.

The other dated rocks provide important constraints. The quartz diorite predates the Screw Creek limestone, and is more foliated than the adjacent Butsih volcanic rocks in whose structural trend it lies. It could be an intrusion which was partly unroofed before Klinkit volcanism. The basalt-gabbro complex is similar in age to felsic rocks of the Big Salmon complex, and may also be partly eroded substrate to the Klinkit assemblage. In contrast, the granite intruding the southwestern exposures of the Klinkit assemblage is Cretaceous. Numerous andesitic intrusions within the Klinkit assemblage are the same age.

AGE-CORRELATIVE SUCCESSIONS

Late Paleozoic–early Mesozoic volcanic and sedimentary successions are abundant in the pericratonic belt between north-central British Columbia and east-central Alaska (some of these are shown diagramatically in the stratigraphic compilation by Colpron and the Yukon–Tanana Working Group, 2001). Here the Klinkit assemblage is compared with Little Salmon succession, the Campbell Range meta-basalt, the Klondike schist, and the Lay Range assemblage.

The dominantly volcaniclastic Little Salmon succession of central Yukon Territory (Colpron, 2001) overlies a prominent white limestone with macrofossils of poorly constrained Late Mississippian–Early Pennsylvanian age (E.W. Bamber, pers. comm., in Colpron and Reinecke, 2000), as well as metamorphosed quartzite, grit and ca. 340 Ma quartz-porphyritic intrusions. The upper part of the succession includes massive flows of intermediate and mafic composition and two cherty horizons which could be exhalative. The andesite and dacite flows probably formed in a continental arc setting, while the trace-element compositions for the mafic flows indicate an ocean-island basalt origin and an alkaline basalt chemistry (Colpron, 2001). Permian and younger strata have not been recognized in the Little Salmon succession.

In the Finlayson Lake district of southeastern Yukon Territory (Fig. 1), several mafic to felsic volcanic suites are older than the prominent late Mississippian to early Pennsylvanian white limestone that also occurs there (*see* Colpron and the Yukon–Tanana Working Group, 2001). Overlying these is the Campbell Range metabasalt, with pink radiolarian chert near its base (Plint and Gordon, 1997). This has been determined to be an unconformable contact (Murphy and Piercey, 1999). This succession ranges from late Pennsylvanian to early Early Permian age. Pyroclastic and felsic extrusive rocks are lacking, while the massive flows and pillow lavas have N-MORB and E-MORB chemical signatures, consistent with generation in an oceanic and/or back-arc/marginal-basin tectonic environment (Piercey et al., 1999). Polymictic conglomerate of mid-Permian age (Murphy, 2001) overlies these rocks.

The Klondike schist of western Yukon (Mortensen, 1990) includes felsic metavolcanic and metaclastic rocks and marble of mid-Permian age. Mafic to intermediate volcanic rocks are lacking. Although possibly contemporaneous, both the Campbell Range basalt and the Klondike schist are fundamentally different geochemically from the Klinkit assemblage, and likely had contrasting tectonic settings.

The Lay Range assemblage in north-central British Columbia contains middle Mississippian to late Middle Pennsylvanian sedimentary and volcanic rocks, overlain by Permian basaltic tuffs and flows with island-arc affinity (Ferri, 1997). The upper mafic tuff division, with Lower Permian radiolarian chert near the base, is dominated by green crystal-lithic and lapilli tuff in which large pyroxene and feldspar phenocrysts are conspicuous. Stratigraphically above is a massive grey limestone (Evans Creek) of Middle Permian to Late Triassic age, overlain by mafic tuffs of the Upper Triassic Takla Group (Ferri, 1997). The latter represents the Mesozoic arc of Quesnellia; on the basis of its age, chemistry, and stratigraphic relations, the underlying Lay Range assemblage is considered by Ferri to be part of the Harper Ranch subterrane (Monger et al., 1991). The upper mafic tuff of this assemblage is a possible correlative to the Klinkit volcanic rocks.

DISCUSSION AND CONCLUSIONS

Klinkit assemblage was originally recognized as one of five contrasting sequences within the pericratonic belt (Dorsey and Slide Mountain terranes) at this latitude (Harms et al., 1997). The age determinations in this report show that the units included in this assemblage span a considerable time range. This broad and lithologically diverse assemblage is now being refined and redefined on the basis of stratigraphy. We now know the following:

1. The Screw Creek limestone is a regionally important formation. Separate exposures yield a spread of ages as old as Viséan and as young as mid-Permian, but those of late Mississippian and early Pennsylvanian age provide the tightest age constraint;

2. The overlying Butsih volcaniclastic unit requires further elucidation of its age and compositional variation. It may correlate with volcanic centres near Mount McCleary to the northwest and the upper mafic tuff division of the Lay Range assemblage. It is important to confirm the Permian age reported here, because it suggests this is a younger arc atop the subjacent Big Salmon complex. It also contrasts with the tectonic setting of Permian volcanic centres in Yukon Territory. The Bigfoot unit may record the waning of this arc; and

3. The Teh unit overlies an unconformity. Its Middle to Late Triassic age overlaps the age of rocks included in the Quesnel terrane although the characteristic associated volcanism is absent.

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