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FIELD GUIDE: QUATERNARY VOLCANISM, STRATIGRAPHY, VERTEBRATE PALAEONTOLOGY, ARCHAEOLOGY, AND SCENIC YUKON RIVER TOUR, FORT SELKIRK AREA (NTS 115 I), YUKON TERRITORY, AUGUST 18-19, 2001

CANQUA WHITEHORSE

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Field Guide: Quaternary Volcanism, Stratigraphy, Vertebrate Palaeontology, Archaeology, and Scenic Yukon River Tour, Fort Selkirk Area (NTS 115 I), Yukon Territory, August 18-19, 2001

Lionel E. Jackson, Jr., Crystal A. Huscroft, Ruth Gotthardt,
John E. Storer and René W. Barendregt

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INTRODUCTION

Unlike most of Canada, large areas of Yukon totally escaped glaciation or remained unglaciated since the Late Pliocene or Early Pleistocene. Consequently, sedimentary sequences ranging from Late Pliocene to Late Pleistocene are common in many parts of western Yukon. The Fort Selkirk area (Fig. 1) has a unique record of Early Pleistocene glaciation and interglacial intervals due to the preservation of glacial and interglacial sediments within or beneath successions of basalt and mafic hyaloclastite. The area also preserves evidence of the late Cenozoic evolution of Yukon River.

Fort Selkirk is located at the confluence of the Yukon and Pelly Rivers. It has been an important fishing and trading location for aboriginal people for thousands of years prior to the start of written history. The short historic period began with the fur trade between aboriginal people and traders with the Russian-American and Hudson's Bay companies. The gold rush of 1898 heralded a full-scale invasion of Yukon by the industrialised world. For example, within a few years, the Klondike area had electrical power generation fuelled by locally mined coal, a local railroad, regular riverboat service during the summer months, a stage line to Whitehorse during winter months, and communication with the outside world by telegraph. Fort Selkirk was an important link in the telegraph, riverboat, and stage line infrastructure. Many local people of middle age or older were born and grew up in Fort Selkirk. It was eventually abandoned in favour of Pelly Crossing following the construction of the Klondike Highway in the 1950s.

This field excursion explores the Late Pliocene to Early and Middle Pleistocene glacial and volcanic history and vertebrate stratigraphy of the Fort Selkirk area. As well, it presents a summary of the archaeological record and history of one of the most scenic ghost towns in northern Canada. Finally, it also offers opportunities to see wildlife and travel down the Yukon River as gold rushers such as Jack London once did.

PHYSIOGRAPHIC SETTING

Our field trip route (Fig. 1), courses its way through a collection of incised plateaus collectively known as Yukon Plateaus (Mathews 1986). It is a rolling upland with broad and generally accordant summits and ridges that typically lie below 1500 m. However, isolated peaks locally reach 1800 m. Former valley-filling basalts of latest Cretaceous age (Carmacks Group) underlie contemporary ridge tops in many areas of central Yukon. They indicate significant erosion and topographic inversion since that time. The rolling morphology of the contemporary Yukon Plateaus with higher mountain groups rising above the generally accordant summits is inherited from a period when the region was eroded to a relative relief of less than about 550 m. The termination of this period of erosion, uplift, and incision of the Yukon Plateaus is poorly constrained because the only rocks younger than Palaeogene basalt flows are Plio-Pleistocene basalt. Previous estimates of the age of this surface have ranged from Eocene to Miocene (Bostock 1936, Tempelman-Kluit 1980). The southward convergence of large high-level valleys and the widening of these valleys in directions opposite to the flow of major

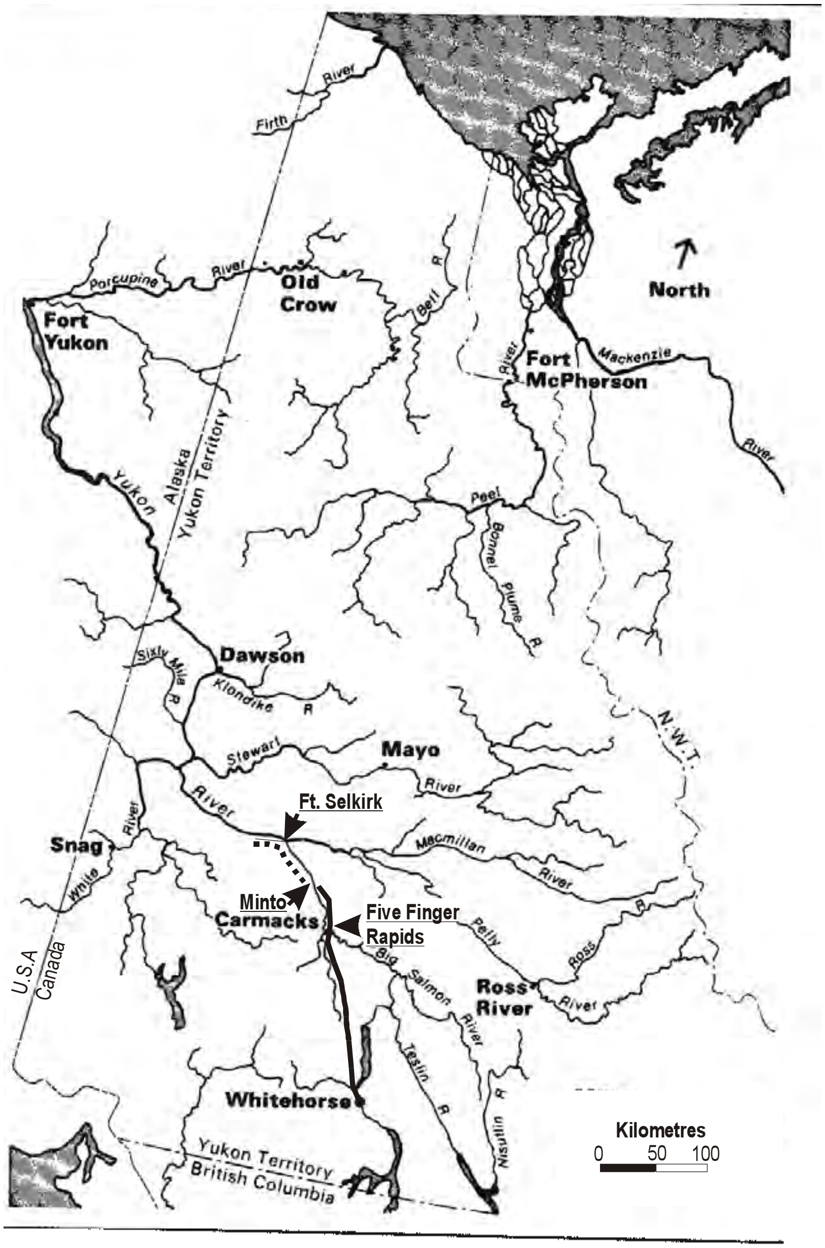

Figure 1. Map of Yukon and field trip route. The solid line indicates the road leg of the trip and dotted line indicates river transport. The trip begins in Whitehorse and ends in the Fort Selkirk area. The first stop is at Five Finger Rapids.

contemporary streams in the Yukon drainage basin, suggests that the contemporary northwest-flowing drainage network was preceded by flow largely to the south (Tempelman-Kluit, 1980).

BEDROCK GEOLOGY

The rocks of central Yukon have been subdivided into tectonostratigraphic terranes by Tempelman-Kluit (1978)[1]. Each terrane includes rocks possessing stratigraphies and tectonic histories distinct and unrelated from adjacent terranes. Terranes are bounded by major structural discontinuities. The Fort Selkirk area (Figs. 2 and 3) includes the Yukon Cataclastic and the Yukon Crystalline terranes and the Whitehorse Trough. These terranes are composed of sedimentary and volcanic rocks and their cataclastic equivalents of Palaeozoic to Jurassic age as well as plutons of Triassic and Jurassic age. The Whitehorse Trough is a former fore-arc basin that received volcanolithic and arkosic clastics from late Triassic through Cretaceous times. These terranes were sutured during episodes of continental accretion by the Middle to Late Cretaceous. Suturing was accompanied by the intrusion of biotite leucogranite, biotite hornblende granodiorite, and hornblende syenite plutons that extensively underlie the areas southwest of Fort Selkirk in the Carmacks 1:250 000 map area (115 I). Intrusion and widespread volcanism occurred during the mid and late Cretaceous with the eruption of Mount Nansen and Carmacks groups. The eruption of the Carmacks Group is most noteworthy: it covered thousands of square kilometres of what is now Yukon Plateaus with andesite flows and related rocks. Renewed but very limited basaltic volcanism occurred in the Fort Selkirk area during the Pleistocene with several eruptions of the Selkirk Volcanics. Volcanic activity in the Fort Selkirk area will be a major focus of this field trip.

CLIMATE

Southern Yukon has a subarctic continental climate with long and bitterly cold winters (dramatically moderating in recent years), short mild summers, low relative humidity and low to moderate precipitation (Table 1). Mild air from the Pacific Ocean intrudes into this region and moderates it from the Arctic climate that characterizes northern Yukon (Wahl and Goos 1987). Microclimates are commonly modified by topographic relief. For example, temperature decreases with increasing elevation during the summer months, but during the winter, extremely cold air is frequently trapped within the Yukon River valley and other major valleys causing a temperature inversion so that air temperatures often increase with elevation (Wahl et al. 1987). Although the climate is periglacial and falls within the zone of widespread permafrost (Brown 1978), extant glaciers are restricted to montane areas in excess of 2000 m where the orographically enhanced mean annual precipitation exceeds 600 mm. None are present in west-central Yukon.

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[1] These interpretations are being re-examined as a part of the Ancient Pacific Margin NATMAP project currently being carried out in Yukon under the combined leadership of Geological Survey of Canada and Yukon Geology Program.

Table 1 Selected Environment Canada climatic data for Carmacks and Fort Selkirk Weather Stations, Yukon

CARMACKS **62° 6'N 136° 18' W** **Elevation 523 m** **Period 1951-1980**	**January**	**July**	**Annual**
Daily mean temperature (°C)	-28.2	14.5	-3.8
Extreme maximum	6.0	35.0	35.0
Extreme minimum	-57.8	-1.1	-57.8
Mean precipitation (mm)	18.4 (snow)	42.3 (rain)	254.3 (rain+ snow)

FORT SELKIRK **62° 49'N 137° 22'W** **Elevation 454 m**	**January**	**July**	**Annual**
Period 1951-1980 **Daily mean temperature (°C)**	-30.2	14.8	-4.7
Extreme maximum	8.3	32.2	35.0
Extreme minimum	-58.9	-2.8	-60.0
Mean precipitation (mm)	20.6 (snow)	49.5 (rain)	286.4 (rain+ snow)

VEGETATION

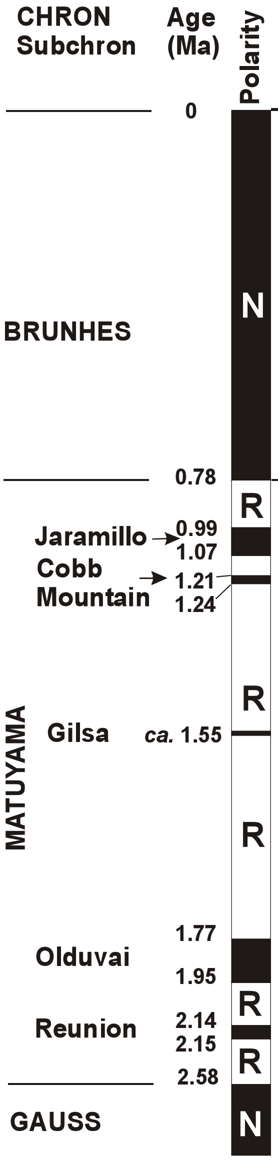
Vegetation in southern and central Yukon is determined by elevation, topography, and microclimate along with the presence or absence of permafrost. In the Whitehorse area where permafrost is sporadic, lodgepole pine (*Pinus contorta*) and white spruce (*Picea glauca*) forest is common. To the north in narrower parts of the Yukon valley where permafrost is nearly continuous, the forest is dominated by black spruce (*Picea marianna*), white spruce, aspen and balsam poplars (*Populus tremuloides* and *Populus balsaminifera*, respectively). Black spruce dominates in poorly drained conditions and commonly indicates the presence of underlying permafrost. Lodgepole pine is scattered along Yukon River on well-drained terraces and is found as high as 1200 m near the summit of Volcano Mountain. Above timberline (at about 1220m) dwarf birch (*Betula glandulosa*) and folious lichens such as *Cladina* spp. *and Claddonia* spp. dominate. Only crustose lichens and scattered herbaceous plants survive at the highest elevations or on steep, unstable or highly exposed areas. Wet areas are dominated by sphagnum mosses (*Sphagnum* spp.) and sedge (*Carex* spp.) bogs.

QUATERNARY CONTEXT

The central and southern Yukon area has been glaciated six or more times since the Late Pliocene (Table 2) based on direct evidence (successions of glacial sediments) and indirect evidence (loess sheets interstratified with beds containing pollen and macrofossils indicative of interglacial conditions). Summaries of evidence for these glacial periods can be found in Jackson et al. (1991), Duk-Rodkin and Barendregt (1997), and Froese et al. (2000). This guidebook will examine direct evidence of glaciation in the area of central Yukon spanning the area between the confluence of Yukon and Pelly rivers and Yukon and Stewart rivers. Bostock (1966) recognized evidence of four glaciations in this region based upon morphostratigraphic, stratigraphic, and geomorphic evidence. These were named Nansen (oldest), Klaza, Reid, and McConnell (youngest). Deposits of the two oldest and most extensive glaciations have been largely removed by erosion or buried by colluvium. Consequently, discrimination between them is not usually possible. Furthermore, the till used to define the Nansen Glaciation appears to have been deposited during the younger Klaza Glaciation (Jackson 2000). The terms Nansen and Klaza are abandoned in this guidebook in favour of the terms older and younger pre-Reid glaciations and their distributions are combined together as pre-Reid glaciations. Table 2 summarises the glacial stratigraphy for west central Yukon in the area of Fort Selkirk based on previous work and work reported in this field guide. The limit of glacial ice cover during the McConnell Glaciation is usually sharply defined by end moraines and ice marginal channels. McConnell-age glacial landforms have sharp crests and McConnell terrain is marked by many small and large lakes. This is in marked contrast to Reid-age terrain where ice-limits and other glacial landforms are usually poorly defined due to a long period of post-depositional erosion or burial beneath McConnell-age aeolian sediments. Pre-Reid sediments have been largely eroded away or buried by colluvium or aeolian sediments. Exceptions occur where thick accumulations of predominantly glaciofluvial fill are present in main valleys. These have commonly been cut into fluvial terraces.

In the Yukon River valley between the village of Carmacks and Fort Selkirk, terraces graded to the McConnell glacial limit can be traced from the Carmacks area to Minto. Terraces graded to deposits of the Reid Glaciation can be traced from the McConnell limit in the Yukon and Pelly river valleys to more than 40 km downstream Fort Selkirk. Pre-Reid age glacial and non-glacial sediments have largely been eroded from the Fort Selkirk area but are locally preserved within and beneath lava flows and hyaloclastite complexes.

Table 2. Glacial, interglacial, and volcanic events and stratigraphy, Fort Selkirk area (after Hughes et al. 1989; Jackson 2000; Jackson et al. 2000, and Huscroft et al. 2001). Geopolarity time scale after Cande and Kent (1995). N.B. time scale drawn to variable scale



Constraining Age(s) (Ma)	Glacial Stratigraphic unit (*informal)	Volcanic eruptions or tephra	Soil	Comments
ca. 0.01		Volcano Mountain lava flows	Stewart (Holocene neosol)	Latest eruption could be as young as mid Holocene
0 .026-0.01	McConnell			
*ca. 0.*130	Reid/McConnell interglacial		Diversion Ck.	Last interglacial?
ca 0.311- *ca* 0.191	Reid Glaciation			
ca 0.311		Pillow point		Yukon River dammed by lava
>0.78- 0.311	several glaciations and interglaciations		Wounded Moose type soils	Buried soils in Mt. Nansen area (Jackson et al. 2000) only known record
ca.1.37--0.78	*younger pre-Reid	Eruption of Ne Ch'e Ddhäwa and valley-filling basalt flows in Yukon and Wolverine valleys		Yukon River dammed and ice contact volcanism (during several eruptions?)
ca. 1.48	Interglaciation?	Holbrook Creek		Maximum age for younger pre-Reid glaciation
ca. 1.54	Interglaciation?	Fort Selkirk Tephra		Maximum age for *younger pre-Reid glaciation, minimum age for *older pre-Reid glaciation
1.83-*ca*. 1.54	*older pre-Reid			Age range based on ages of lower Mushroom lava flow and Fort Selkirk tephra
ca. 1.83		Mushroom		Maximum age for *older pre-Reid glaciation
2.7-1.83	One or more ice sheets in Fort Selkirk area	2.7 Ma from an Ar-Ar age determined on basalt along Rosebud Ck. (Huscroft et al. 2001)	Wounded Moose type soils	First regional glaciation and reversal of ancestral Yukon River during this period

THE LAST CORDILLERAN ICE SHEET IN YUKON

Only the events of the last (McConnell) glaciation are known in any detail (Jackson et al. 1991) and serve as a model for interpreting the older glaciations. Hughes et al. (1969) assigned names to semiautonomous sectors of the McConnell age Cordilleran ice sheet in southern Yukon. These sectors are defined in Figure 2. The Selwyn Lobe flowed west from Selwyn Mountains and shared a common ice divide with the Liard Lobe along the Continental Divide. The Cassiar Lobe flowed west and northwest from the Cassiar Mountains. It was separated from the Selwyn Lobe by Pelly Mountains. The Liard Lobe flowed south from Selwyn Mountains and southeast and east, respectively, from Pelly Mountains and Cassiar Mountains. Pelly Mountains supported complexes of ice caps that shed ice to the Cassiar and Selwyn lobes as well. The Eastern Coast Mountain Lobe, which flowed northwestwards from the summits of the Eastern Coast mountains in northwestern British Columbia, was intermediate between the piedmont lobe complex originating in Saint Elias Mountains and the Cassiar Lobe. Areas formerly covered by the Eastern Coast Mountain Lobe, Cassiar Lobe, and Selwyn Lobe are traversed during our travel from Whitehorse to Fort Selkirk in that order.

CONTEMPORARY AND FOSSIL SOILS

Soils formed during the Holocene (neosols) are widespread and fall mainly into the Regosolic Order in steep areas and above tree line and into Gleysolic and Organic orders in poorly drained locations. However, Cryosols are present where permafrost is within one metre of the surface and Brunisols dominate under well-drained forest conditions (Tarnocai 1987). Soils developed on deposits of the last (McConnell) glaciation (largely Brunisols) have been named the Stewart neosol. Little alteration of the mineralogy of the McConnell age parent material has been noted in these soils (Tarnocai 1987). Two paleosols are found beyond the McConnell glacial limit. In addition to strictly pedologic differences from the Stewart neosol, they are commonly cut by ice-wedge pseudomorphs and sand wedges and are capped by or contain ventifacts. The Diversion Creek paleosol is believed to have developed during the last (Sangamonian) interglacial period ca. 128-115- ka (Smith et al. 1986; Tarnocai et al. 1985). These soils, again predominantly Brunisols, are up to two times thicker than their McConnell equivalents, have B horizon colours the same or slightly more intense than the Stewart neosol and frequently have Bt horizons with thin clay skins on ped surfaces. In the Fort Selkirk area, these soils survive at the surface on glaciofluvial terraces (Tarnocai 1987). They are also seen in cliff bank exposures where they are buried beneath McConnell-age loess and alluvial fan sediments (Ward 1993, p. 74).

The Wounded Moose paleosol developed on drift of the pre-Reid glaciations during the Early Pleistocene. This paleosol has been truncated by erosion such that only part of its B-horizon is preserved. The Wounded Moose paleosol is dramatically different from Stewart neosol and Diversion Creek paleosol. Solum thicknesses reach 2 m. Bt horizons (enriched in clay due to illuviation) are deeply weathered with thick clay skins present on pebbles and ped surfaces. These clay skins are the product of the deposition (illuviation) of clay eroded and transported from former A-horizons that have long since eroded. Munsell soil colours range from

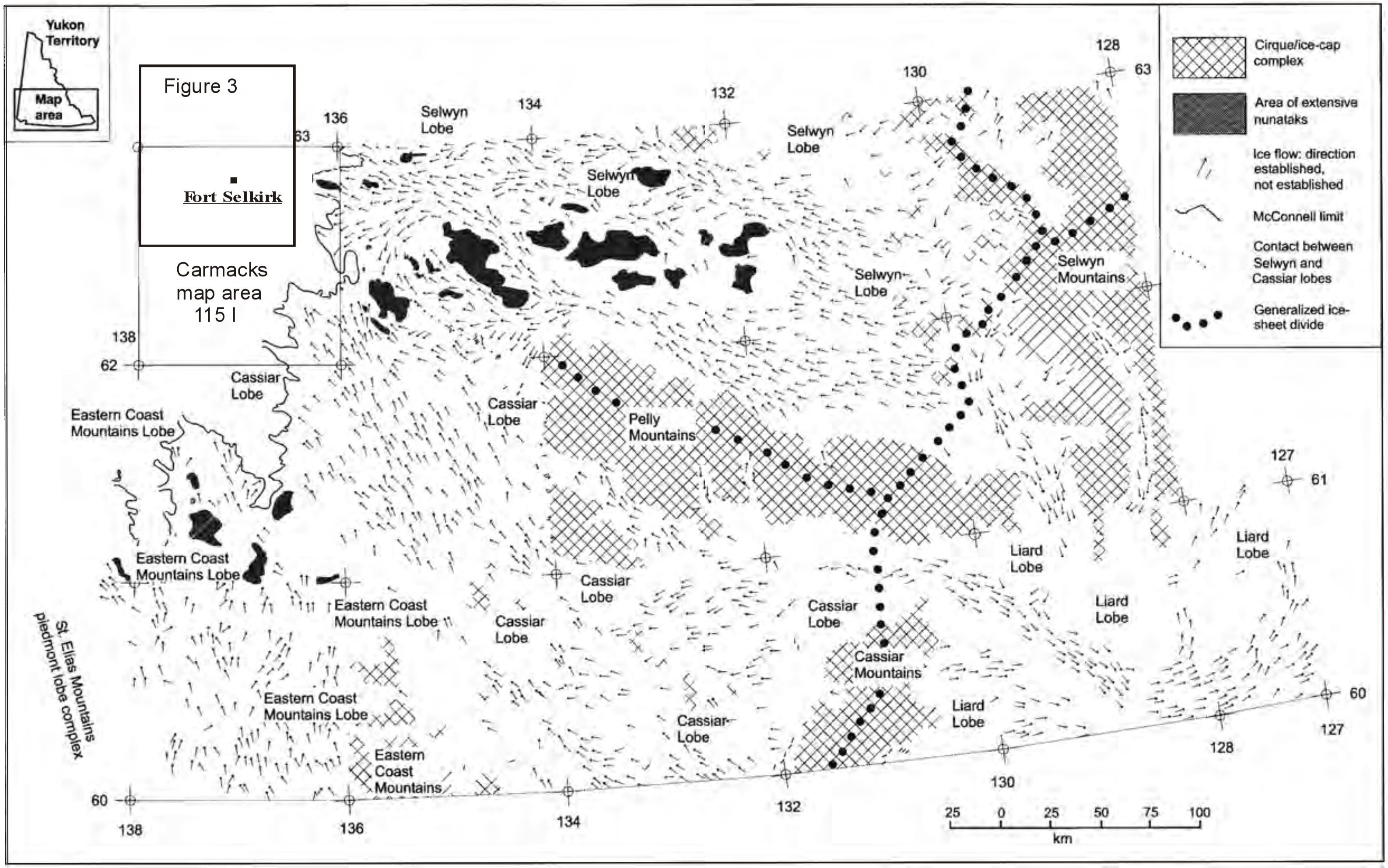


Figure 2. Sectors and flow directions of the last (McConnell age) Cordilleran ice sheet in southern Yukon Territory (from Jackson, 2000).

5YR for outwash and 7.5YR for till parent materials. This is in contrast to the 10YR colouration that characterizes Stewart and Diversion Creek soils (Tarnocai 1987). Despite their colouration, their sodium pyrophosphate extractable Fe and Al contents are too low to qualify them as Podzols under the Canadian Soil classification scheme (Canada Soil Survey Committee 1978) and most closely resemble a Luvisol under that scheme (Smith et al. 1986). Analysis of the mineralogy of B-horizon clays led Foscolos et al. (1977) to conclude that Wounded Moose soils developed under a climatic regime significantly warmer and more humid than those prevailing during the formation of the Diversion Creek and Stewart soils. The Wounded Moose soils formed under a mean annual temperature at least 7 °C warmer than the present one which is well below 0 °C (Table 1). Mean annual precipitation also exceeded 500 mm at the time of Wounded Moose soil formation.

FIELD TRIP GUIDE--DAY 1

Leaders: Lionel Jackson, Ruth Gotthardt, and Maria Van Bibber

We depart Whitehorse, capital of Yukon Territory, following the Alaska Highway and then turning north onto the Klondike Highway towards Dawson City. Whitehorse (the name was in common use by 1887 (Coutts 1980)) is situated at the upper limits of steamboat navigation on Yukon River. Rapids upstream, from which the city gains its name, presented a barrier to navigation. The Klondike gold rush in 1898 (the actual Bonanza Creek discovery was made in 1896) prompted the construction of the White Pass and Yukon Railway to Whitehorse in 1899. In the same year, rich copper deposits were discovered in the area. Whitehorse grew dramatically because of the construction of the Alaska Highway during the Second World War. This road was built by the United States Army as a secure land route to Alaska in the event of a Japanese invasion (the Japanese Imperial Army did invade and occupy parts of the Aleutian Island chain during that conflict). In 1951, the capital of Yukon was moved to Whitehorse from waning Dawson City. About 70% of Yukon's population resides in the Whitehorse area. Yukon (population about 33,000) is approximately one-and-a-half times the size of the State of California (population about 33,000,000).

Our first formal stop will be near the glacial limit of the McConnell Glaciation, about two hours drive. On the way, there are a few points of interest and glacial features to look out for:

Glacial Lake Champagne sediments

Immediately beyond Whitehorse city limits (about 15 km from downtown), we cross the Takhini River and see fine exposures of glaciolacustrine sediments. Stagnation of the Cordilleran Ice Sheet at the close of the McConnell (Late Wisconsinan) Glaciation caused the formation of an extensive glacial lake in this part of southern Yukon (Glacial Lake Champagne). Sediments from this Glacial Lake Champagne also form the prominent bluffs along either side of downtown

Whitehorse.

Streamline landforms and rounded summits

From the Whitehorse area, the Klondike Highway traverses terrain which was covered by the Eastern Coast Mountains and Cassiar lobes of the Cordilleran Ice Sheet during the McConnnell Glaciation. The thickness of the ice was generally greater than local relief. Consequently, summits and ridges along the way are rounded and classic alpine landforms such as cirques, horns and arêtes are absent from the area. Although ice locally flowed across ridges, overall ice flow directions were controlled by the underlying valley systems. Nunataks were extensive only in the vicinity of ice limits.

Large north-south trending valleys containing lakes or underfit streams

The Klondike Highway follows the major north-south trending valleys occupied by Fox Lake and the underfit Nordenskiold River. Tempelman-Kluit (1980) proposed that these valleys may have been cut by a south flowing predecessor of Yukon River during preglacial times. He argued that successive Cordilleran ice sheets advanced from south to north, in opposition to preglacial stream flow. This diverted drainage northwest into central Alaska forming the contemporary Yukon River system.

Landslides, unglaciated terrain and topographic reversal west of Carmacks

Massive landslides have occurred in the Carmacks Group at the east end of Miller Ridge west of the village of Carmacks (these will be visible from stop 1-1). The top of the ridge totally escaped glaciation as did ridges of comparable elevation in this area. The ridge is composed of a volcanic succession that filled a broad valley of at least 500 m depth. The reversal of topography (former valley floors are now ridges around 800 m above contemporary valley bottoms) gives an indication of the relatively modest amount of regional erosion over the past 70 million years (about 10 m per million years).

The village of Carmacks is named in honour of George Washington Carmacks, one of the discoverers of the incredibly rich gold placers of Bonanza Creek in 1896.

Stop 1-1 Five Finger Rapids overlook (199 km from Whitehorse)

At Five Finger Rapids, we are about 10 km upstream from the McConnell glacial limit. After reaching its maximum extent, the outlet glacier from the Cordilleran Ice Sheet that flowed down the Yukon valley stagnated and retreated filling the valley with thick drift. One small readvance occurred during overall stagnation and retreat (Jackson 2000, p. 15). The drift blocked the preexisting valley and caused the Yukon River to establish a new course through Mesozoic conglomerate and sandstone of the Laberge Group along the eastern margin of the valley. Four bedrock islets divide the river into five channels or fingers that form the rapids.

The current through the Five Fingers was too strong for paddlewheel steamers to ascend the rapids. They were winched up through them. With the construction of the Klondike Highway, river steamers became unprofitable. The last one navigated the Five Fingers in 1956.

We will now press on to meet our river boats at Minto, our next stop.

Tatchun Creek Crossing and McConnell limit outwash and Reid outwash

At Tatchun Creek Crossing, the Klondike Highway follows the outwash plain from the McConnell glacier terminus. The former outwash plain descends rapidly toward contemporary river level.

Stop 1-2 Minto Resort

The village of Minto was a riverboat fuelling stop and the site of a roadhouse on the Whitehorse/Dawson stage road. The village was abandoned and razed in the 1950s. It was named in 1900 to honour Lord Minto, the Governor General of Canada at that time. The sites of the original village and the present resort are situated on a terrace graded to the terminus of the Cordilleran Ice Sheet during McConnell glaciation. The terrace progressively descends in a downstream direction. At Minto, we will board two riverboats operated by Big River Enterprises for our trip down the Yukon to Fort Selkirk. Some notable historic, wildlife, and geologic sights are listed below. Distances are measured along Yukon River from Minto.

Minto Bluff (km 5-7)

Minto Bluff is also called ‘Sheep Mountain’ for good reason. Look for a small herd or individual Dall sheep on its slopes.

Hells Gate (km 22)

Although this stretch of the river will not be a problem for us to navigate, the large steamboats of bygone days commonly became grounded on the ever-changing gravel bars of this wide and shallow reach of Yukon River. Between 1900 and 1911, large sums of money were spent to build wing dams from shore. Their purpose was to concentrate the flow in order to keep mid-channels deep enough for reliable passage. Very little is left of these structures. Look for large iron rings set in bedrock cliffs in this area. The steamboats used these to winch off shoals when they became grounded (sometimes for weeks).

Mouth of Wolverine Creek and Ne Ch’e Ddhäwa volcano (km 26-32)

To the west (left bank) is the mouth of Wolverine Creek and the first glimpse of basalt flows of the Selkirk volcanics. To the east downstream is the Ne Ch’e Ddhäwa volcanic edifice. The name ‘Selkirk Volcanics’ was given by Bostock (1936) to a complex of basaltic lava flows, pillow basalts, pillow breccias and altered tuffs in the area of Fort Selkirk (Figs. 3-5b). They will be addressed in more detail tomorrow. The cumulative thickness of basalt flows exposed along the gorge of Wolverine Creek exceeds 100 m. The basalt flows infill much of the preglacial Yukon Valley and the preglacial landscape of Wolverine Creek basin. They consist of multiple flow units of massive to columnar basalt separated by flow breccias and complexes of foreset-bedded pillows. The latter represent delta-like deposits created as lava flows entered deep standing water (Jackson et al. 1996). The Ne Ch'e Ddhäwa volcanic edifice[2] (Figs. 5a and b), composed of altered tuffs, pillow tuff breccias and pillow basalts, rises almost 300 m above Yukon River. Jackson (1989) and Jackson et al. (1990, 1996) demonstrated that Ne Ch'e Ddhäwa is a tuya (erupted beneath glacial ice) based upon its predominant pillow tuff breccia composition, local inclusions of masses of glaciogenic diamicton, and capping of pillow basalts containing exotic pebbles. The hyaloclastites of Ne Ch'e Ddhäwa are magnetically reversed and palaeomagnetically identical to the basalt flows filling Yukon and Wolverine valleys.

Ne Ch'e Ddhäwa is at least partly underlain by clastic sediments with normal magnetisation. Only the upper few metres of these semi-lithified sediments are exposed. These have yielded pollen indicative of a forested environment similar to that of the present day (Mott *in* Jackson 2000). The pollen-bearing sand beds are separated from the base of the hyaloclastite succession by a clayey diamicton that may be a till. This unit and the upper part of the underlying sandy beds are deformed into isoclinal folds. It is not clear whether this is due to glacial tectonism, loading by the overlying volcanic rocks, or drag folding due to movement along the normal fault a few tens of metres to the north.

Ne Ch'e Ddhäwa is ringed by a moraine from the Reid Glaciation but it lacks deposits of older tills at higher levels. Consequently, it is thought to have erupted beneath the younger of the two pre-Reid ice sheets to leave evidence in the Fort Selkirk area. Its reversed magnetisation indicates that this glaciation occurred prior to the last magnetic reversal at 0.78 Ma. The north (downstream) end of the edifice is in apparent normal fault contact with basalt flows. If so, this is one of the few demonstrably Pleistocene faults in the area.

Cape Diamond (Nose palaeomagnetic sampling site) from Reversing Slough (km 35)

The current in Reversing Slough, at the confluence of Yukon and Pelly rivers, can run either way depending on whether the Yukon River or Pelly River is at a higher stage. To the east is the original site of Fort Selkirk founded in 1848 by Robert Campbell of the Hudson’s Bay Company. It had to be abandoned in 1850 in favour of the present site due to chronic flooding. To the north west, across Pelly River, is an impressive basalt palisade. The promontory overlooking the confluence of the two rivers was originally called “Cape Diamond” by Campbell, and “Nose” by Jackson et al. 1996 to designate a palaeomagnetic sampling site (both are unofficial names). The

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[2] Ne Ch’e Ddhäwa is the aboriginal name for this officially unnamed mountain.

stratigraphy of the cliff consists of a lava flow capping many tens of metres of pillow breccia with a foreset bedded structure. This type of succession forms where a lava flow enters deep standing water. Pillows form and may tumble to the lake or sea floor. This forms an angle-of-repose slope builds outward and progressively shallows to the point that subaerial lava flows can advance over the pillow breccia. This gives the appearance of the foreset and topset succession in a Gilbert delta. Bostock (1966) reported glacial striations locally on top of the capping flows thus indicating that it was glaciated during one of the Pre-Reid glaciations. It is reversely magnetised as are Wolverine Creek and Ne Ch'e Ddhäwa lava flows and hyaloclastites. Patches of unweathered gravel on the top of Cape Diamond mark the downstream limit of the Cordilleran ice sheet ice during the Reid Glaciation in the Yukon valley. The ice sheet terminated about 14 km up stream of the confluence in the Pelly River valley (Fig. 3).

If the weather is clear, Volcano Mountain, about 17 km to the north, will be visible looking up the Pelly River canyon from the Pelly-Yukon confluence. This cinder cone last erupted between the mid Holocene and the end of the Pleistocene (Jackson and Stevens 1992).

Stop 1-3 Fort Selkirk Town site (km 38)

At Fort Selkirk, we disembark onto the McConnell terrace to set up camp for the night and prepare for a walking tour of the town and an introduction to its history. The tour leader is Maria Van Bibber, a member of the Selkirk First Nation, who was born and raised in Fort Selkirk. She is the resident interpreter at this historic site. The archaeology of this area is covered in a separate publication *A look back in time, archaeology of Fort Selkirk* by Ruth Gotthardt and Greg Hare who are archaeologists with Yukon Heritage Branch in Whitehorse. Additional copies of this informative booklet can be obtained from Yukon Heritage Branch.

FIELD TRIP GUIDE DAY 2-- GEOLOGY AND PALAEONTOLOGY OF THE SELKIRK VOLCANICS AND THE HISTORY OF YUKON RIVER

Leaders: Crystal Huscroft, John Storer, René Barendregt and Lionel Jackson

The Selkirk Volcanics are isolated to extensive volcanic rocks erupted from volcanic centres in central Yukon (Fig. 3). They are most extensive in the area of the confluence of the Yukon and Pelly Rivers, the area of Volcano Mountain and the Wolverine Creek basin. They are predominately alkali olivine basalt, nephelinite and basanite (Frances and Ludden 1990, Huscroft et al. 2001; Fig. 4). These volcanic rocks are locally interstratified with glacial and nonglacial sediments (Owen 1959a and b; Jackson et al. 1990, Jackson et al. 1996; Jackson 1997, 2000). Volcanic centres are concentrated along known faults and lineaments of uncertain origin. The Fort Selkirk area is situated at the intersection of the northwest trending Teslin Fault and an east-to-west-trending lineament that controls the courses of the Pelly River east of Fort Selkirk and Yukon River west of the town. Three periods of eruption were identified by Jackson et al.

(1996). However, recent work has demonstrated that there have been at least five eruptive

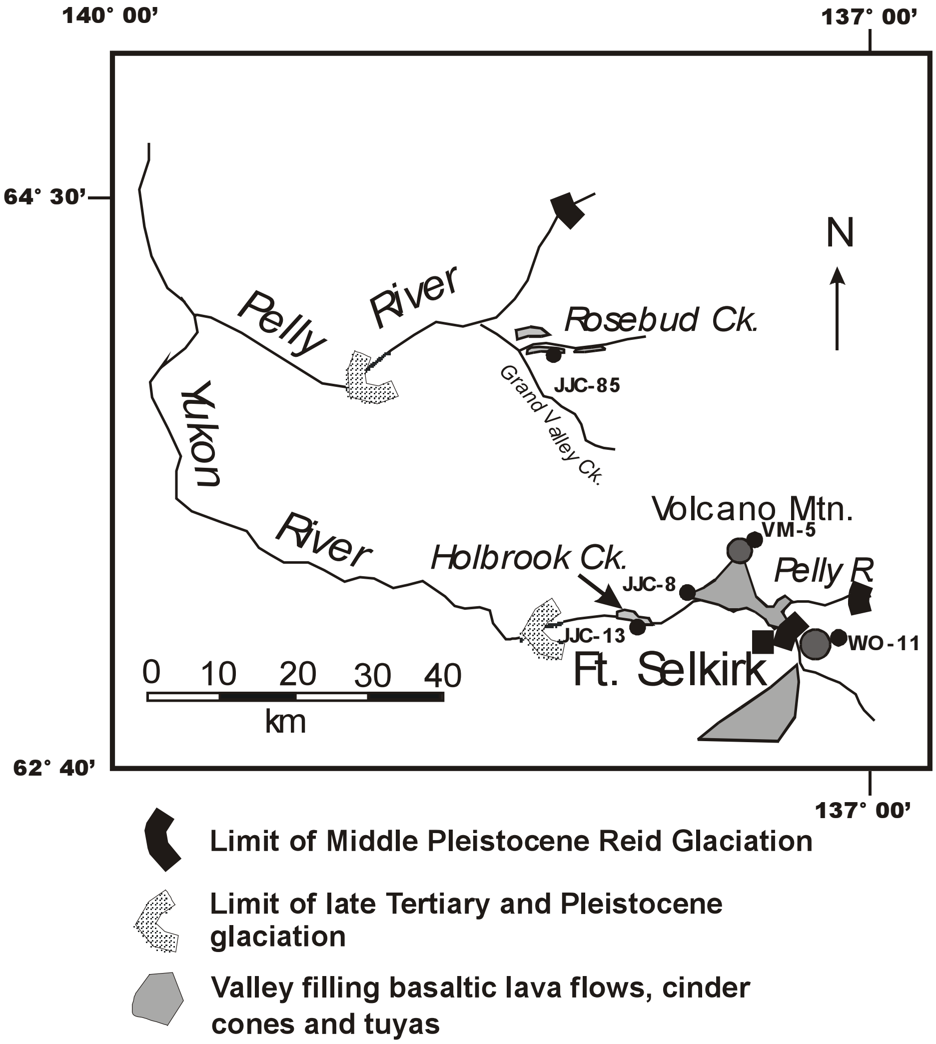

Figure 3. Location of Selkirk Volcanics and related rocks discussed in the text Sample numbers refer to samples whose compositions are shown in Figure 4.

periods in the Fort Selkirk area (Table 2). Furthermore, work to the north in the Rosebud Creek area has identified a sixth period which occurred ca. 2.7 Ma which apparently predates the initiation of glaciation in west central Yukon. Age-control for these eruptive periods comes from direct dating of basalt by Ar-Ar dating, bracketing of eruptions in time through palaeomagnetic investigations with reference to the geopolarity time scale (Cande and Kent, 1995; Table 2), establishment of maximum and minimum ages through fission track dating of interstratified Fort Selkirk tephra (source in the Aleutian Islands) and establishment of minimum ages of the youngest flows by carbon-14 dating of the oldest organic sediments in lava-dammed lakes.

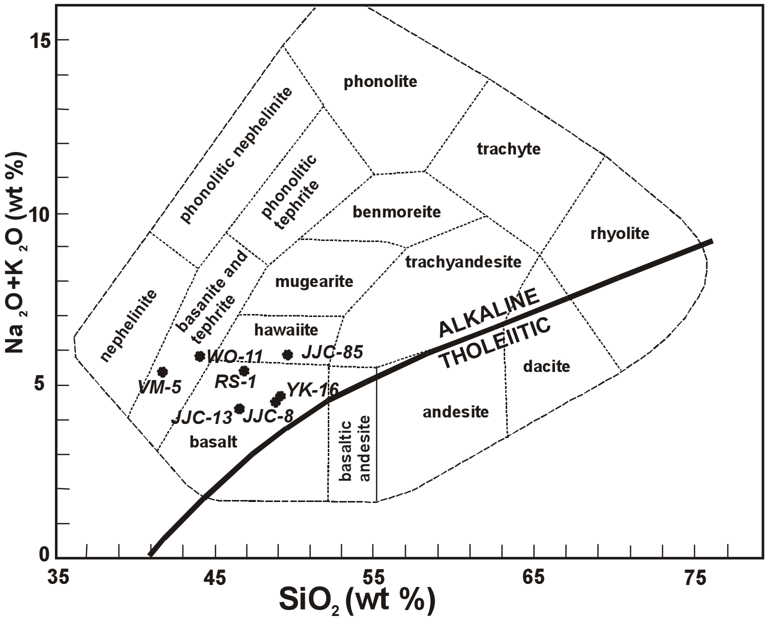

Figure 4. Plot of alkali versus silica for selected samples of Selkirk Volcanics. Samples beginning with JJC were collected by Crystal Huscroft; others were supplied by Don Francis, McGill University.

Eruptive Periods, Ages of Glaciations, and History of Yukon River

A summary of eruptions and glaciations in the Fort Selkirk area is presented in Table 2. This summary is based on compilation of many stratigraphic exposures. Key sections for the Fort Selkirk area are shown in Figures 5a and b. Only a few of these will be visited as a part of this field trip. Supporting information for Figure 5b is presented in Tables 3 and 4.

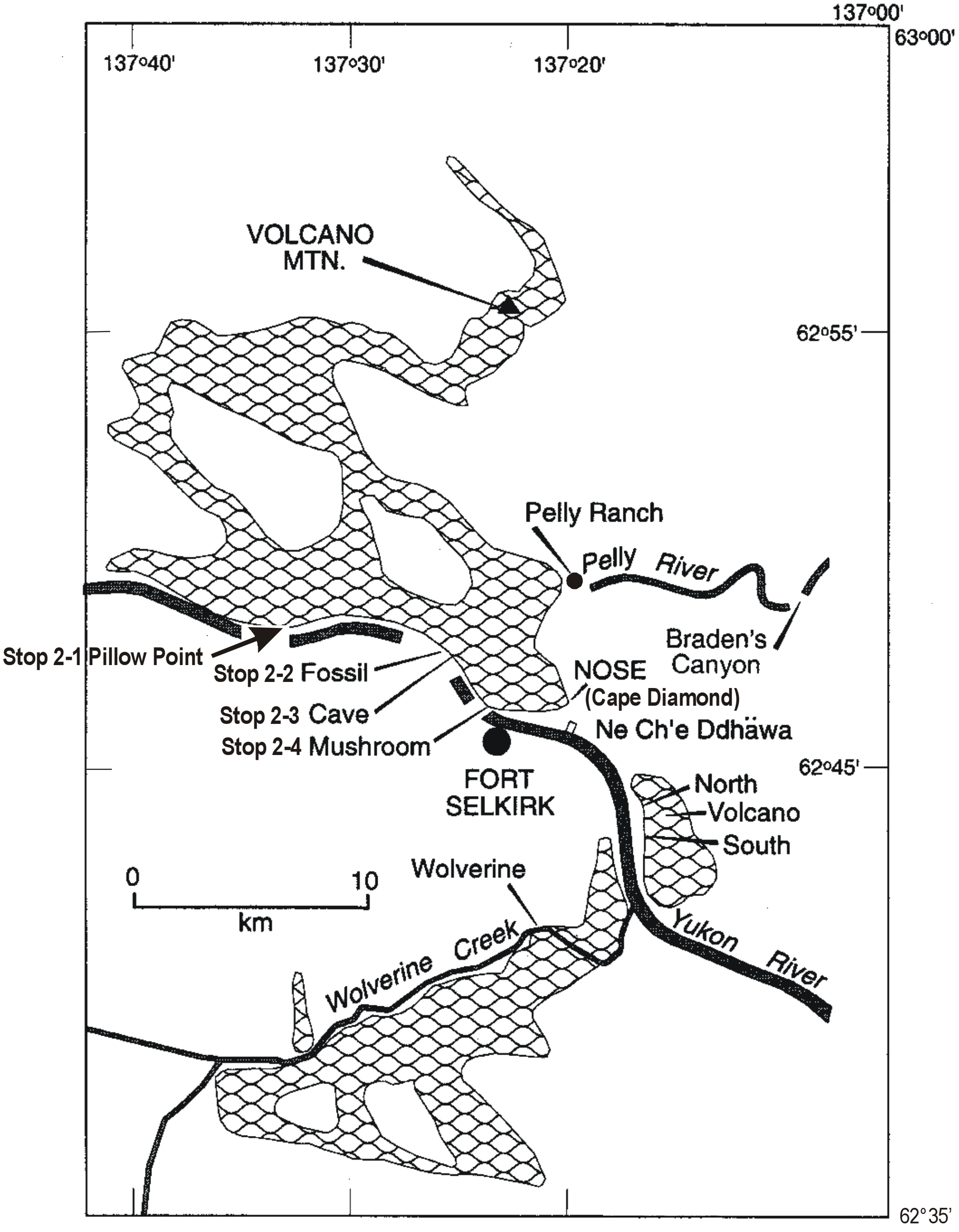

Figure 5a Selkirk Volcanics (honeycomb pattern) in the area of Fort Selkirk, stops on Day 2 and location of sections depicted on Fig. 5b.

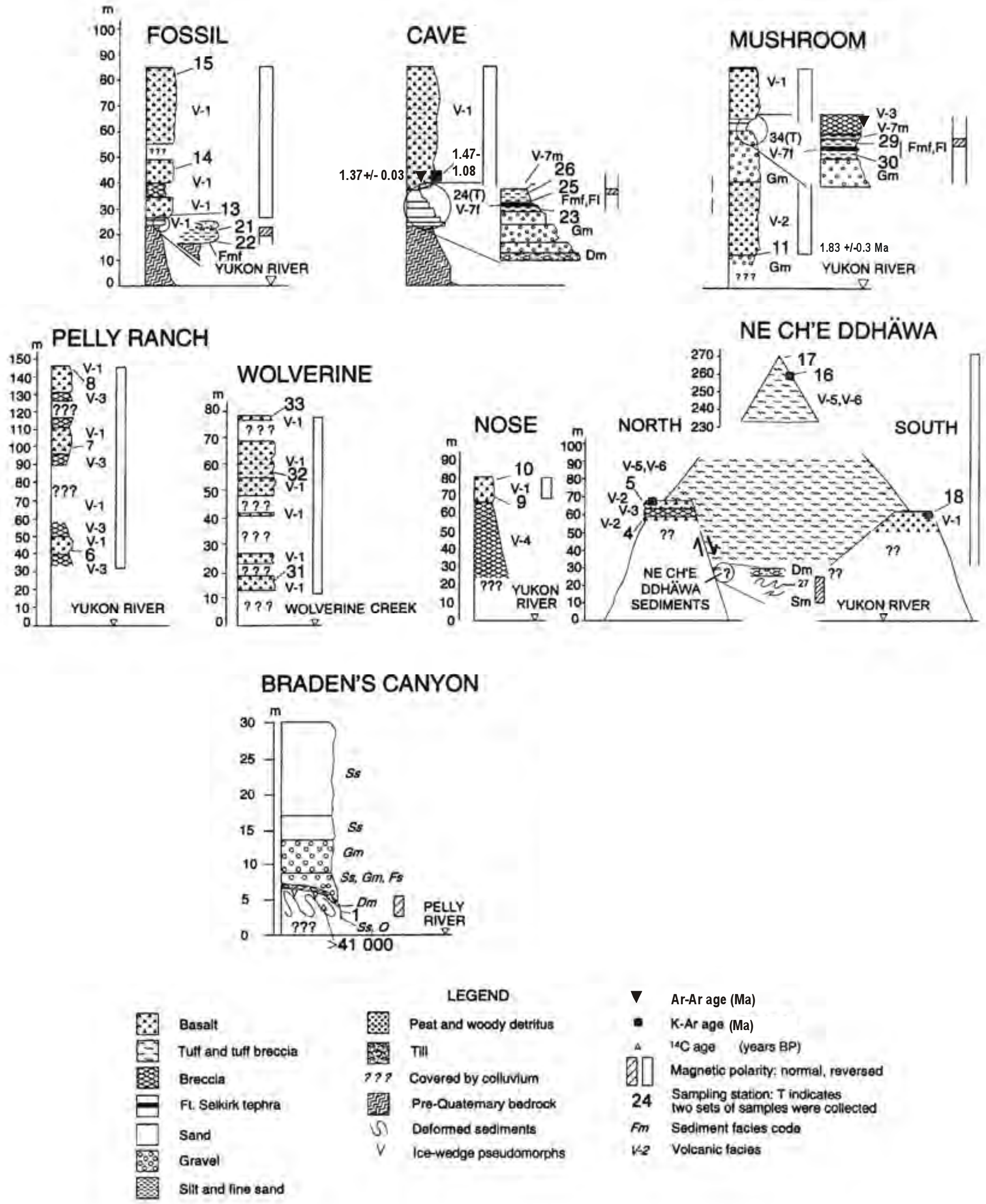

Figure 5b. Summary of sedimentary and volcanic facies and sample sites modified from Jackson et al. 1996. Braden's Canyon will not be visited. Facies are are explained in Tables 3 and 4.

Table 3 Sedimentary facies shown in Figure 5b (after Jackson et al. 1996)

Facies	Texture	Stratification and sedimentology	Depositional environment
Dm	Stony diamicton, sandy to clay loam matrix	Massive and fissile; has a strong unimodal pebble fabric; stones are faceted and striated and have a regional provenance; underlying sediments are sheared, folded, and thrusted	Glaciogenic: lodgement or melt-out till based upon texture, stratification, and sedimentology (Dreimanis 1989; Ward 1989)
Gm, Gs	Poorly sorted gravel and minor sand (Mushroom section (upper gravel), and Cave section)); well-sorted gravel (Mushroom section (basal gravel)	Massive (Gm) and planar (Gs)	
		Mushroom section (upper gravel) and Cave section: poorly sorted; clasts angular and have a regional provenance; conformably overlies Dm	Glaciofluvial: distal outwash based upon stratification and sedimentology and location of sediments 50 m above Yukon River
		Mushroom section (basal gravel): clasts rounded, imbricated, and consist of resistant local and regional lithologies	Fluvial or distal glaciofluvial; may predate glaciation?
		Revenue Creek: poorly sorted; clasts angular, with lithology restricted to the Revenue Creek drainage basin	Fluvial: braided stream – alluvial fan based upon local clast lithology, angularity, and incised valley environment of the deposits
Sm, Sg, Ss	Medium to coarse sand	Massive (Sm), normally graded (Sg), and planar bedded, rippled or cross-stratified (Ss); the three facies are usually interstratified; beds are lensoidal and intercalated	Fluvial (Braden's Canyon section below Dm, Revenue Creek, and Ne Ch'e Ddhäwa sediments sections): bar, channel, and lacustrine flood-plain deposits; palynological and other paleoenvironmental data indicate deposition during interstade or interglacial (Ward 1989; Mott, written communication, 1990; H. Jetté, written communication, 1995; A.M. Telka, written communication, 1995); glaciofluvial and fluvial (Braden's Canyon section above Dm): McConnell Glaciation outwash and Holocene stream-channel deposits (Ward 1993)
S-o	Sand, peat, logs, woody debris	Planar bedded, cryoturbated	Fluvial and colluvial (Revenue Creek): flood-plain channels and bars and toes of colluvial slopes; deposition under alternating glacial and interstadial climatic regimen (H. Jetté, written communication, 1995; A.M. Telka, written communication, 1995); fluvial (Braden's Canyon section): bar and channel deposits (Ward 1993)
Fmf	Inorganic silt and very fine sand	Massive: at Fossil section, texture 85 wt.% within the 4–8 μm size range	Aeolian: loess, based upon texture alone (Swineford and Frye 1945; Péwé 1951); limb bones of *Rangifer* sp. (caribou) and a lagomorph (rabbit or hare) about the size of *Lepus arcticus* (C.R. Harington, personal communication, 1991) found in sediments at Fossil section and teeth from *Lasiopodomys* sp. (primative vole) at Cave section are consistent with an aeolian environment and Early Pleistocene age (C.R. Harington, personal communication, 1993)
Fl	Inorganic silt and very fine sand	Laminated to thinly bedded	Lacustrine: includes resedimented loess; sediments at Cave section contain laminae of degraded moss
Fl-o	Organic and inorganic silt (muck) and very fine sand	Laminated to thinly bedded; sediments cryoturbated	Fluvial: flood-plain and colluvial deposition under alternating glacial and interstadial climatic regimen (H. Jetté, written communication, 1995; A.M. Telka, written communication, 1995)

Table 4. Volcanic facies noted in Figure 5b (modified from Jackson et al. 1996)

Facies	Thickness (m) Area (m^2)	Association	Architecture and lithology	Eruptive environment
V-1: columnar and blocky jointed basalt	4–5 10^5-10^6	Typically overlies V-3 and V-4	Colonnade–entablature successions; colonnades composed of prismatic basalt columns 30–100 cm in diameter	Vertical jointing and large aerial extent indicate emplacement as subaerial lava flows (Waters 1960)
V-2: "war bonnet" columnar basalt (after Waters 1960)	3–10 10^2-10^4	Contacts V-3 and V-5 laterally and vertically and overlies V-3	Radially fanning, recumbent, and contorted basalt columns, which locally give the impression of feathers arrayed on a war bonnet	Fanning and recumbent columns are indicative of subaqueous or subglacial eruption and flow (Mathews 1958; Roddick et al. 1977; Bergh 1985; Bergh and Sigvaldson 1991)
V-3: subflow breccia	<1 10^3-10^4	Underlies V-1 and V-2 and grades vertically downward into V-4	Oxidized and altered angular and vesicular fragments of basalt; fragments range from <1 to 30 cm; pillows and pillow fragments are common	Subflow breccias form from fragmentation of the basal zone of lava flows due to rapid quenching where they traverse damp ground or shallow water
V-4: foreset-bedded pillow breccia and massive pillow breccia	5–65 10^5-10^6	Overlain by V-1, with V-3 locally present as an intervening transition zone	Accumulations of basalt pillows and pillow fragments; these may form foreset beds; pillows commonly have fresh rinds of sideromelane up to 2 cm thick	Foreset-bedded pillow breccias form when lava flows advance into deep water, whereas massive pillows are indicative of eruption within water (Russell 1902; Fuller 1931; Jones and Nelson 1970; Moore et al. 1973; Furnes and Fridlefsson 1974; Furnes and Sturt 1976)
V-5: pillow tuff breccia	200 10^5	Intergrades with V-4	Basalt hyaloclastite breccia: a chaotic mixture of angular pillow fragments in a matrix of sandy tuff altered to kaolinite, mixed-layered clays, and zeolite stratification commonly deformed by syndepositional slumping	Makes up most of the Ne Ch'e Ddhäwa volcanic edifice; contains exotic pebbles incorporated during subglacial eruption of Ne Ch'e Ddhäwa (Jackson 1989; Hickson 1986, 1990)
V-6: stratified massive tuff and tuff breccia	0–100 10^5	Grades into V-5 toward volcanic centre	Altered, stratified basaltic tuff and lapillite; original pyroclasts have been altered to kaolinite, mixed-layered clays, zeolite (analcime), albite, and calcite	Fine texture, hyaloclastite lithology, exotic pebbles, and position at the margin of Ne Ch'e Ddhäwa are consistent with a distal subglacial volcanic eruptive environment
V-7m: Partly fused sediments	1–2 10^5	Overlain by V-1 and V-3	Strongly resembles vesicular glassy welded lapilli	Partly melted and fused volcanoclastic gravel, sand and silt.
V-7f: felsic ash	10–20 cm 10^4?	Interstratified with fine sand	Primary ash bed is commonly succeeded by thin, impure, reworked beds of ash, silt, or fine sand	Tephra from a remote felsic volcanic centre (Naeser et al. 1982)

Mushroom eruption, older pre-Reid glaciation and Fort Selkirk Tephra

The oldest eruptive event known in the Fort Selkirk area occurred immediately across the river (north) of the town site (figs. 5a and b). The war bonnet-like array of radially jointed columns and hyaloclastite that characterize this flow has a mushroom-like appearance. Hence, Jackson et al. (1996) assigned this name to the site and the eruption. The Mushroom flow is the lower of two lava flow complexes separated by a 5 m thick sedimentary sequence (Fig. 5b). The Mushroom flow complex is Ar-Ar dated at 1.83 ± 0.03 Ma (Mike Villeneuve, personal communication (2000) reported in Huscroft et al. (2001)) and is consistently magnetically reversed. This supersedes a preexisting whole rock K-Ar age of 1.60 ± 0.08 (Westgate 1989)[3]. This flow will be visited at stop 2-4 today.

Maximum and minimum ages for the oldest glacial (Fort Selkirk Glaciation) sediments in the Fort Selkirk area

The oldest till recognized in this area was deposited during the older of two pre-Reid glaciations represented in the area (informally called older pre-Reid glaciation from here on). It occurs at only one site, called Cave (stop 2-3, Figs. 5b, 6, 7E). It contains blocks of unweathered olivine basalt but it is not seen to overlie the Mushroom flow directly. The till is abruptly overlain by a fining upward gravel to sand sequence interpreted to be outwash based upon its abundant content of erratic pebble lithologies Fig. 7C and D), basal contact on a till, and position approximately 25 m above the flood plain of Yukon River (the top of the gravel underlying the Mushroom flow has half that relief). There is no evidence of weathering of the till or other relationships indicating a hiatus between deposition of the till and the overlying outwash. It is concluded that the two units are products of the same glaciation. At the Mushroom site (stop 2-4), the same gravel unit rises to 60 m above the Yukon River flood plain and it directly overlies the 1.83 Ma basalt (the till was either eroded out from this site or never deposited). Hence, the underlying basalt assigns a maximum age to the older of the two pre-Reid glaciations recognized in the area. The outwash sequence is overlain by non-glacial sediments containing the Fort Selkirk Tephra at the Cave and Mushroom sites (Figs. 5a and b). The tephra clearly is magnetically reversed.

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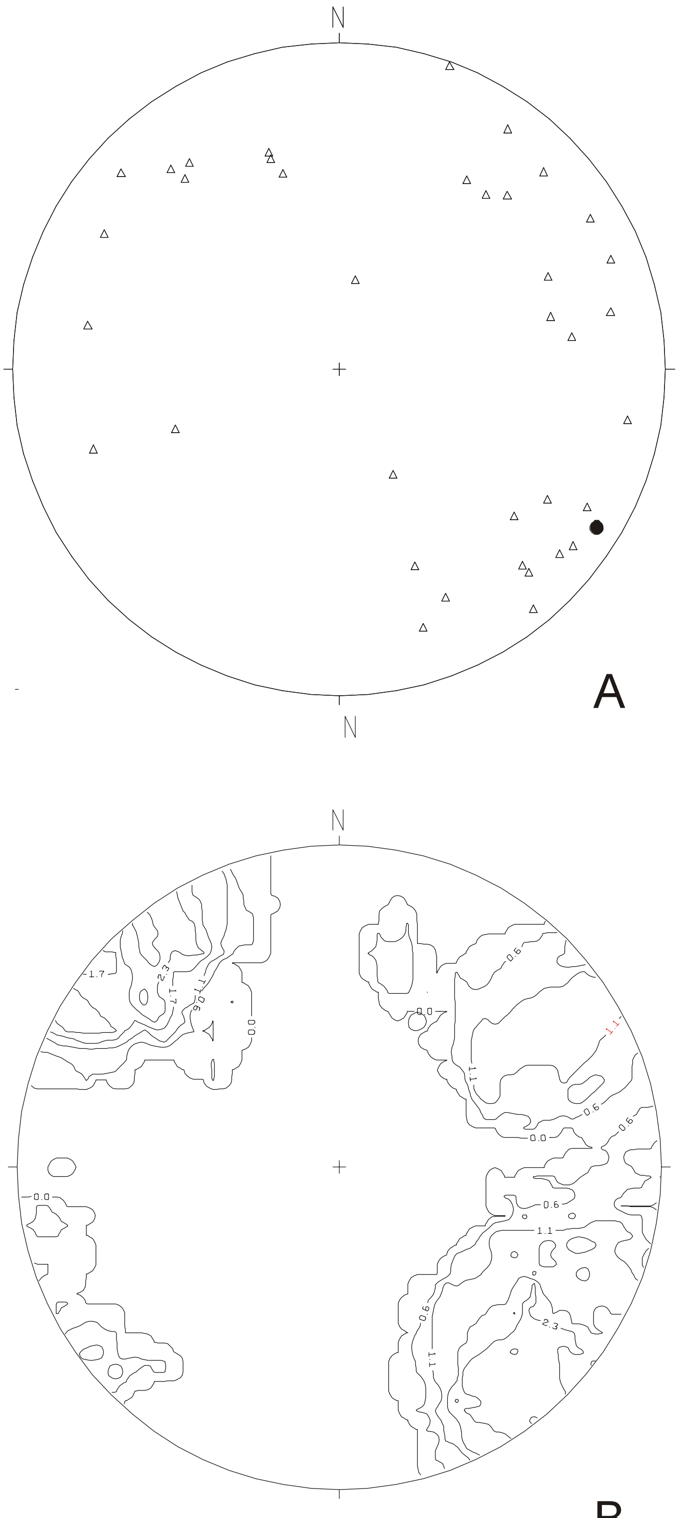
[3] Whole rock K-Ar ages have been found to be unreliable for many of the lava flows in the Fort Selkirk area by Jackson et al. (1996). Lava flows which are demonstrably the same age based on palaeomagnetics have yielded ages differing by up to several Ma. This is apparently due to mantle argon trapped in the basalts. This is not surprising because many of the lava flows in the area contain mantle xenoliths (Sinclair et al. 1978). The Ar-Ar method addresses this problem and is considered the more reliable method. However, the K-Ar ages reported by Westgate (1989) from the Cave site have proven to agree well with the newly determined Ar-Ar age.



PRE-REID TILL, Stop 2-3

Projection	Schmidt
Number of points	37
Mean lineation azimuth	121.4
Mean lineation plunge	7.0
1st Eigenvalue	0.503
2nd Eigenvalue	0.351
3rd Eigenvalue	0.146
E1/E3	0.359
E2/E3	0.880
[E1/E3]/[E2/E3]	0.408
Spherical variance	0.5233
Rbar	0.4767

△ Pebble long axis azimuth and plunge

● Mean azimuth and plunge

Figure 6. Pebble fabric (A) and contour plot (B) determined on pre-Reid till at stop 2-3 (Cave site). Eigenvalues are significant at the 99% probability level.

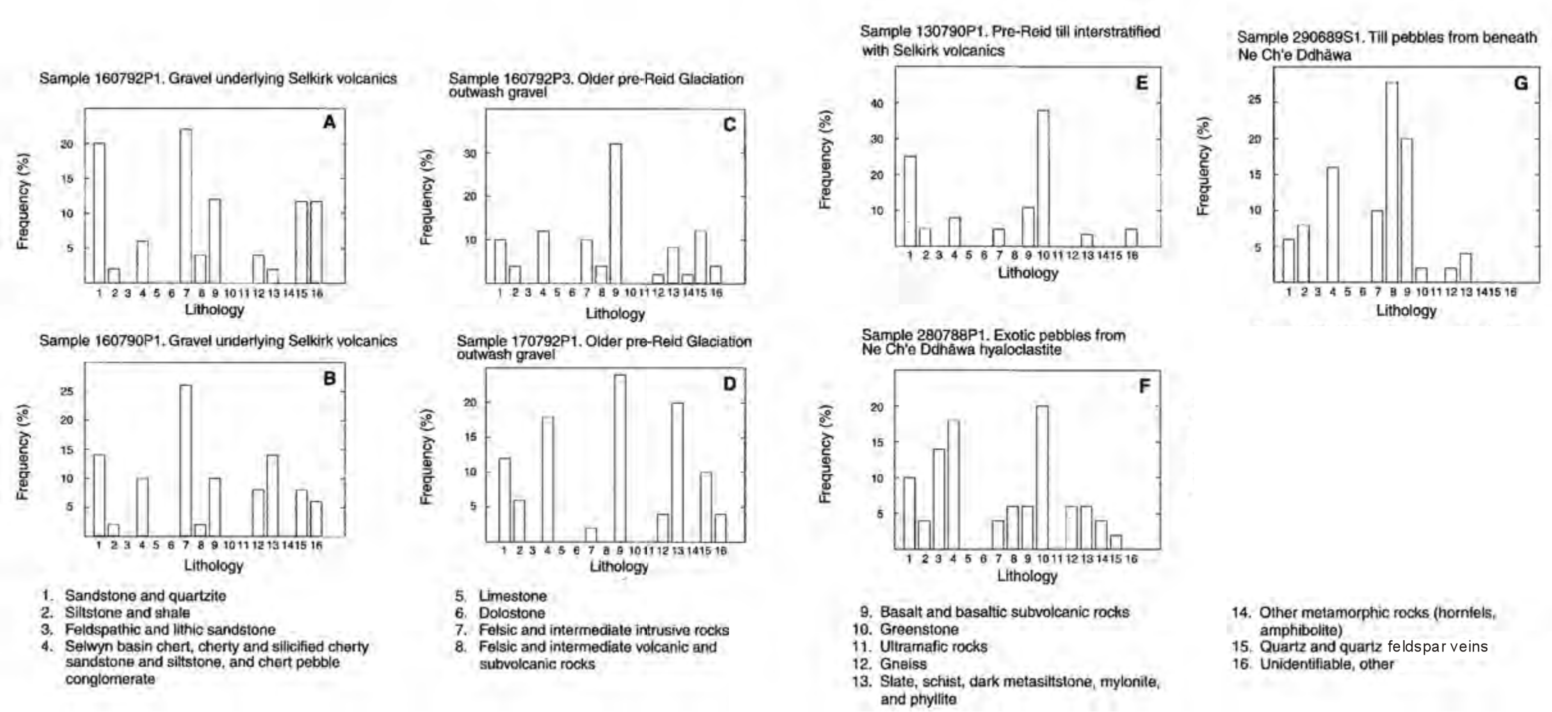


Figure 7. Lithologies of A) and B) gravel underlying the Selkirk Volcanics at Stop 2-4 (Mushroom); C) and D) pre-Reid outwash interstratified with Selkirk Volcanics at stops 2-3 (Cave) and 2-4 (Mushroom); E) pebbles in pre-Reid till at Stop 2-3; F) exotic pebbles incorporated in Ne Ch'e Ddhäwa hyalocalstite; G) pebbles from diamicton underlying Ne Ch'e Ddhäwa (after Jackson 2000)

Isothermal plateau method fission track (IPFT) ages (Westgate 1989; Table 2) constrain the tephra to the Matuyama Chron between the end of the magnetically normal Olduvai Subchron (1.77 Ma) and the beginning of the magnetically normal Jaramillo Subchron, (1.07 Ma; Cande and Kent 1995). The ages of the Mushroom eruption and the Fort Selkrik Tephra and their magnetic polarities thus constrain the older pre-Reid glaciation to the same period. Furthermore, Ar-Ar dating of the younger valley-filling basalts which stratigraphically overlie the Fort Selkirk Tephra and a new age interpretation of an intervening magnetically normal horizon further limit the age range of the older pre-Reid glaciation to 1.77- ca.1.55 Ma (see **Ne Ch'e Ddhäwa eruptions** below). We suggest that this well dated Early Pleistocene glaciation be named the 'Fort Selkirk Glaciation'.

Implications for the history of Yukon River

Gravel is exposed below the oldest flow at Mushroom section at an elevation of 10 to 14 m above the Yukon River flood plain. The age of the Mushroom flow assigns a maximum age to the underlying gravel. This in turn allows an estimate of the maximum rate of incision by the Yukon River of about 0.8 cm/ka since ca. 1.83 Ma. The composition of the gravel underlying the lava flow is quite mixed and is dominated by lithologies from more that 100 km upstream (Fig. 7, A and B) rather than by local lithologies such as greenstone. This is in marked contrast to *bona fide* preglacial gravel units such as the White Channel Gravel that were derived from deeply weathered terrain present at the end of the temperate Tertiary Period. Based on this, Jackson (2000, p. 20) suggested that the Fort Selkirk area had been glaciated prior to the deposition of the basal gravel at Mushroom section. He observed that clast imbrications in this gravel indicate paleo-flow to the north-west. This is the same flow direction as the contemporary Yukon River.

Tempelman-Kluit (1980), Jackson (2000), and Duk-Rodkin et al. (2001) advanced the hypothesis that the original late Tertiary flow of the ancestral Yukon River within west-central Yukon was to the south. They further suggested that reorganisation of drainage to the north-west was the result of glacial diversion due to the advance of Cordilleran Ice Sheets from south to north in Yukon in opposition to preglacial drainage. If so, the north-west paleo-flow recorded in the gravel further suggests that one or more ice sheets had inundated the Fort Selkirk area and reversed the flow of the Yukon River prior to 1.83 Ma, the age of the lava flow overlying the basal gravel.

Holbrook Creek eruption

An isolated remnant of a magnetically reversed olivine phyric basalt flow occurs 30 km down the Yukon River from Fort Selkirk near the mouth of a stream locally known as Holbrook Creek (Huscroft et al. 2001; Figs. 3, 8 and 9). It overlies a gravel deposit 30 m above the contemporary Yukon River flood plain. Pillows and gas escape structures at its base indicate that the gravel was wet at the time of eruption and was likely at the surface of the Yukon River flood plain level at the time of the eruption. An Ar-Ar age of 1.48 ± 0.05 Ma has been determined on this flow (Huscroft et al. 2001). Colluvium and discontinuous gravel overlying the flow contain glacial

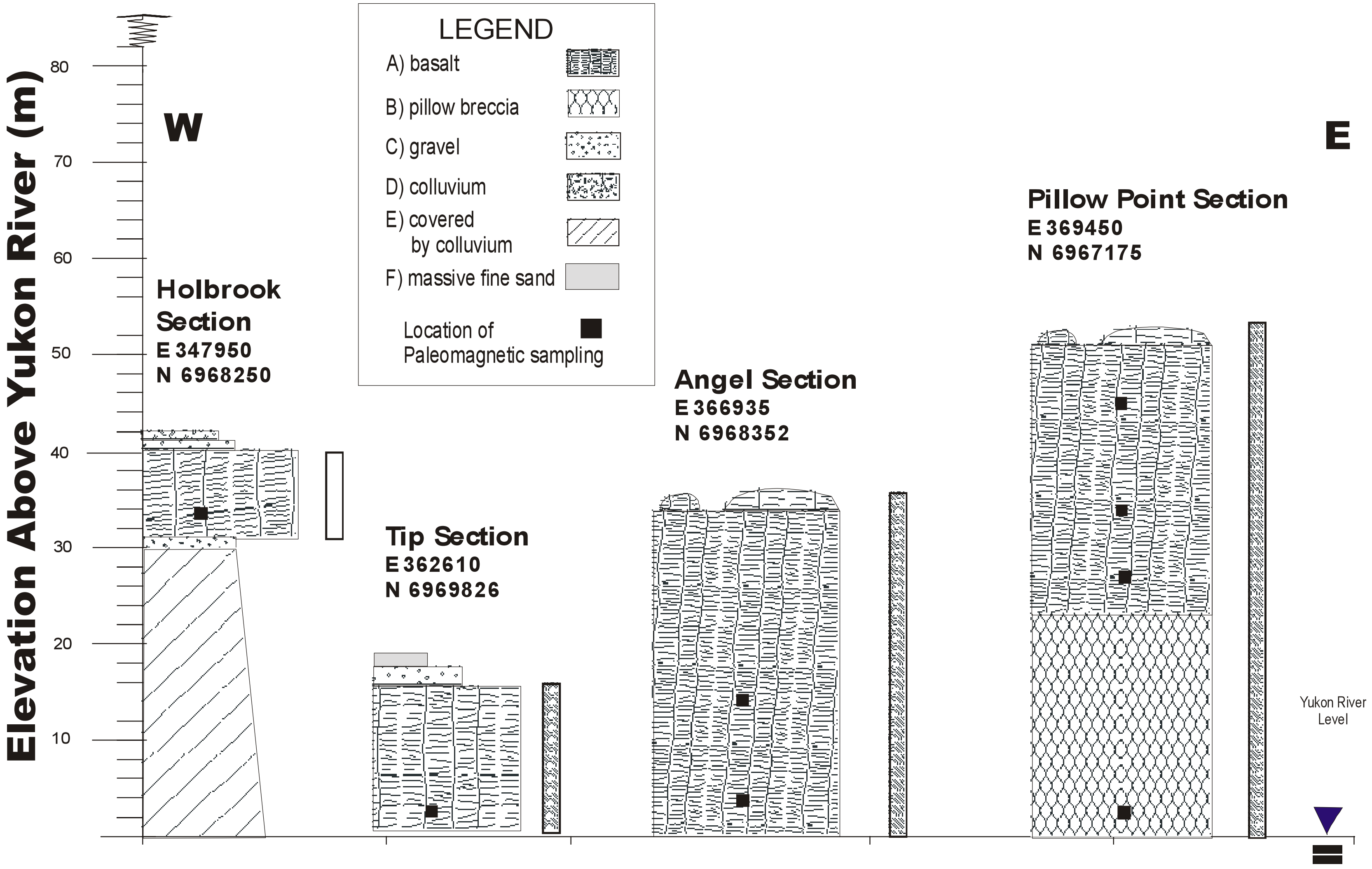


Figure 8 Summary of volcanic stratigraphy and volcanic facies between Pillow Point and Holbrook Creek. Shaded bars adjacent to sections indicate normally magnetised rocks whereas unshaded bars indicate reversely magnetised rocks. The Yukon River descends approximately 8m from east to west from approximately 430 m above sea level at Pillow Point.

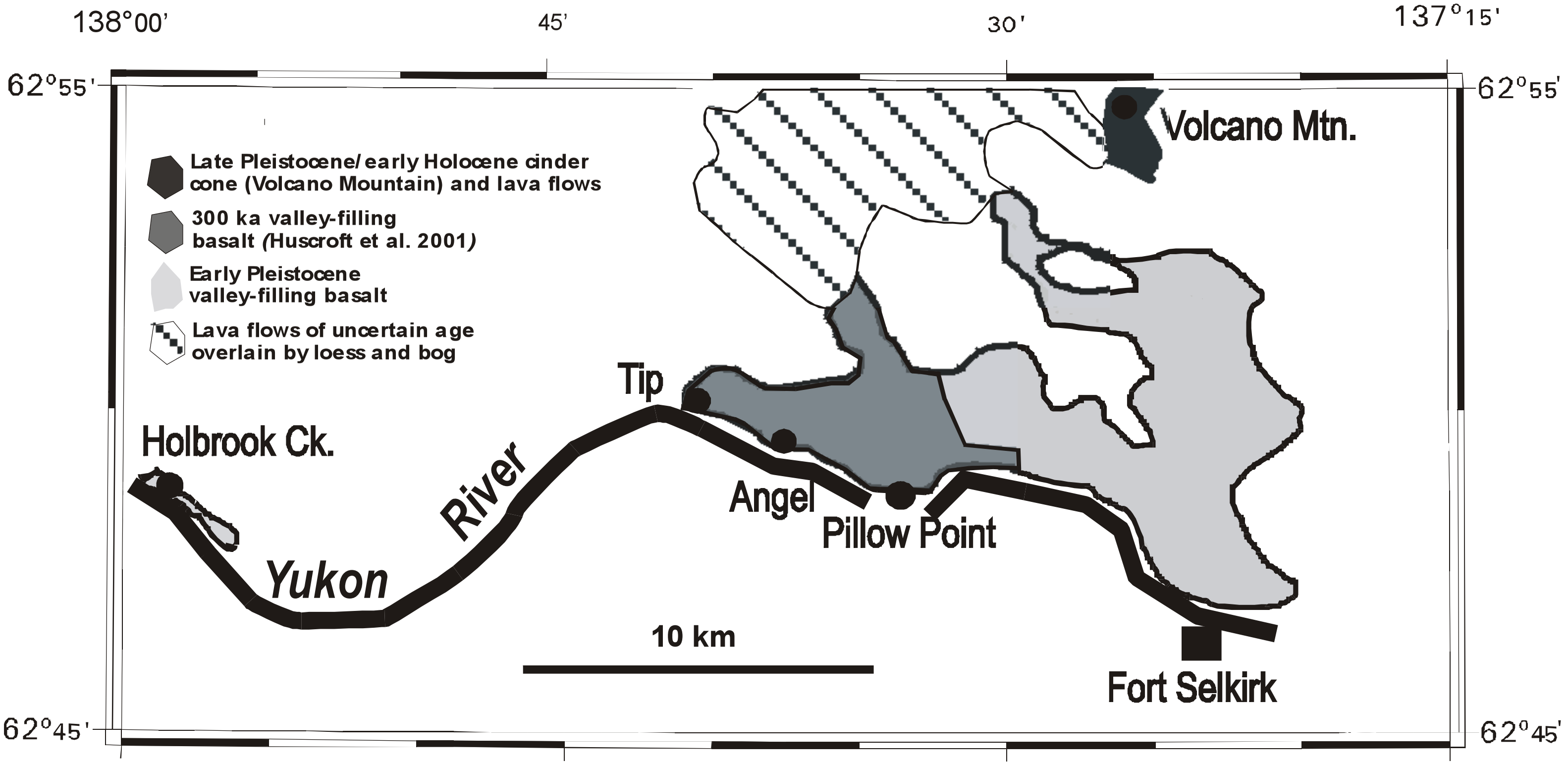


Figure 9. Ages of major surface lava flow complexes along Yukon River downstream and north of Fort Selkirk.

erratics from central Yukon. The source of the flow is unknown. However, there are no remnants of it up nearby tributary creeks. Therefore, a vent in the Yukon River valley is suggested.

Maximum age for younger Pre-Reid glaciation

The Ar-Ar age of the flow post-dates the constraining ages for the older pre-Reid glaciation in the Fort Selkirk area. If overlying gravels are outwash, its eruption predates the younger of the pre-Reid glaciations recognised on the basis of deposits in the Fort Selkirk area. Its age is also younger than the mean age range of isothermal plateau fission track age for the Fort Selkirk Tephra (Westgate 1989). Consequently, it provides a constraining maximum age for the younger pre-Reid glaciation in this area.

Implications for the history of Yukon River

The Holbrook Creek basalt flow and underlying gravel puts constraints on the history of Yukon River similar to the *ca.* 1.83 Ma Mushroom flow and underlying gravel in the Fort Selkirk area (see above). The basal gravel at Holbrook Creek has a similar composition to the basal gravel at Fort Selkirk and has a strong imbrication also indicating flow to the west. The average rate of incision of Yukon River is slightly over 1cm/ka at Holbrook Creek and is similar to the value determined at Mushroom.

Ne Ch'e Ddhäwa eruptions

The most extensive eruptive period includes the eruption of many cubic kilometres of extensive valley-filling basalt in the Yukon River valley, Wolverine Creek and the subglacial eruption of Ne Ch'e Ddhäwa during the younger pre-Reid glaciation (Figs 5 a and b; Jackson et al. 1996). This period of eruptions will be informally and collectively referred to as the Ne Ch'e Ddhäwa eruptions. Foreset beds of basalt pillows and breccia indicate that basalt lava flows dammed the Yukon and Pelly rivers in the area of Cape Diamond (Nose palaeomagnetic site, Figs. 5 a and b). The Ne Ch'e Ddhäwa flows show a westerly bias in the direction of their measured remanent magnetic fields. Jackson et al. (1996) argued that the bias recorded short-term secular variation. This infers that the eruptions occurred over a few hundred years. However, there are geologic reasons to doubt this. The thick succession of foreset-bedded pillow breccia succeeded by a lava flow at Cape Diamond (Nose) records a damming of the Yukon and Pelly rivers and apparently occurred under ice-free conditions. The uppermost flow in this succession has striations on it indicating that the eruption predated the incursion of the younger pre-Reid ice sheet (Bostock 1966). The maximum elevation of thick pillow breccia facies on Ne Ch'e Ddhäwa indicates that the volcano erupted under at least 300 m of ice. Hence, there must have been a hiatus between the two eruptions. Further Ar-Ar dating and new palaeomagnetic work may further clarify the chronology.

The basalt flows and hyaloclastites from the Ne Ch'e Ddhäwa eruptions consistently are magnetically reversed. Furthermore, they overlie sediments containing the Fort Selkirk tephra and a normally magnetised sediment sequence and at two locations. This sequence of Fort Selkirk tephra succeeded by a magnetically normal interval was formerly thought by Jackson et al. (1996) to constrain these eruptions to the last reversed interval of the Matuyama Chron between 0.99 and 0.78 Ma (Table 2) or immediately prior to the brief Cobb Mountain normal polarity event. The Cobb Mountain is dated at 1.19 Ma by Shackleton et al. (1990) and between 1.201 and 1.211 Ma by Cande and Kent (1995). Four whole rock K-Ar ages have been determined on the lava flows erupted during the Ne Ch'e Ddhäwa eruptions at the Cave site (Figs. 5 a and b; Stop 2-3). These are (in Ma) 1.35 ± 0.08, 1.35 ± 0.11, 1.47 ± 0.11 (Westgate 1989) and 1.08 ± 0.05 (Naeser et al. 1982). A new Ar-Ar age of 1.37 ± 0.03 Ma has been determined on these flows. This age corroborates three of the previous K-Ar ages and eliminates the possibility that the normally magnetised sediments overlying the Fort Selkirk tephra were deposited during either the Cobb Mountain or Jaramillo normal subchrons. The ca. 1.55 Ma Gilsa Subchron (McDougal and Wensink 1966; Watkins et al 1975; Clement and Kent 1987) occurred during the interval bounded by the ages of the Mushroom and the Ne Ch'e Ddhäwa eruptions (Table 2). Duane Froese of the University of Calgary (2001 personal communication), in collaboration with John Westgate (University of Toronto), René Barendregt (University of Lethbridge) and Randy Enkin (GSC), was the first to conclude that the thin normal magnetic interval in the Cave and Mushroom sections was deposited during the Gilsa Subchron, following release of the new Ar-Ar ages on bracketing basalts by Mike Villeneuve (GSC). The 1.55 Ma age determined for the Gilsa Subchron [4] (Clement and Kent 1987), is statistically indistinguishable from the mean IPFT age on the Fort Selkirk Tephra (1.54 ± 0.27 Ma) which directly underlies the thin magnetically normal intervals at Cave and Mushroom sites. The presence of normal remanent magnetization from the Gilsa Subchron in these sediments corroborates the IPFT ages on the tephra, and creates a new minimum limiting age of ca. 1.55 Ma for the underlying glacial sediments from the older pre-Reid glaciation (Froese et al. 2001).

Age of the younger pre-Reid glaciation

As noted above, the upper basalt flows at Cave and Mushroom sites are locally striated and they are overlain by discontinuous drift of youngest of pre-Reid Cordilleran ice sheets. The Ar-Ar age of 1.37 ± 0.03 Ma on these basalts places a maximum age on the incursion of this glacier. Ne Ch'e Ddhäwa is inferred to have erupted under this ice sheet and it is uniformly magnetically reversed. Consequently, the limiting minimum age for the youngest of pre-Reid ice-sheets to enter the Fort Selkirk area is ca. 0.78 Ma, the age of Matuyama/Brunhes magnetic reversal. New Ar-Ar dates on the subglacial eruption on Ne Ch'e Ddhäwa will be determined during the next few years. These should date the younger pre-Reid glaciation directly.

Pillow Point eruption

Jackson et al. (1996) grouped all surface lava flows exposed along the Yukon River as the

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[4] The magnetic field may have been normal for as little as 500 years during this event (Clement and Kent 1987).

product of one eruption (Figs. 5a, 8, 9). Paleomagnetic sampling was restricted to the area of Fort Selkirk and the flows farther downstream were assumed to be extensions of Ne Ch'e Ddhäwa-age flows. However, new work by Huscroft et al. (2001) showed that the downstream 10 km portion of the complex (Fig. 9) is a product of a much younger period of volcanic activity. This conclusion is based upon:

- a geomorphic discontinuity in the surface profile of the basalt valley fill,
- uniformly normal magnetisation of the downstream flows,
- termination of the flows below the present flood plain level,
- lack of any drift on the surface of the lava flows, except for Reid age outwash downstream from the confluence of Yukon River with Black Creek,
- an Ar-Ar age of 311 ± 30 ka (Huscroft et al. 2001).

These flows constrict the Yukon River canyon to approximately 1 km one of its narrowest reaches. Huscroft et al. (2001) reported a pillow breccia complex up to 30 m thick within the upstream portion of these flows. In the area which she informally named "Pillow Point" along the north side of the Yukon River, foreset-bedded pillow breccia radiates and dips towards the modern channel of the Yukon River. The breccia and its radial pattern strongly infer that the eruption dammed the Yukon River. A 30 m lava dam could have created a lake which extended as much as 60 km up the valleys of the Yukon and Pelly rivers. Furthermore, a bed of 1 m and larger boulders downstream from Pillow Point suggests that the lake drained following catastrophic dam breaching.

Implications for the age of the Reid Glaciation

The lava flows from the Pillow Point eruption were in place by the time outwash from the Reid age Cordilleran Ice Sheet caused the Yukon floodplain to aggrade at least 30 m along this reach of the Yukon River. The Reid Glaciation predates ca. 190 ka, the age of the Sheep Creek tephra (Westgate 1989) that locally overlies the Reid drift in central Yukon. A radiometric age on basalt downstream from Pillow Point places a maximum age on this glaciation of about 311 ka. These ages bracket the Reid Glaciation within oxygen isotope stage 8.

Implications for the history of Yukon River

The Pillow Point lava flows characteristically terminate below river level. This indicates that the Yukon River reached its present level before 311 ka BP and has only aggraded and degraded in response to volcanic damming and glacial advances and retreats since that time.

Volcano Mountain eruptions

Volcano Mountain, which may have been visible on day one of this field trip, is a cinder cone 17 km north of Fort Selkirk. Lava flows broke out of the base of the southwest side and have poured out of the summit crater along the northeast side (Jackson and Stevens 1992). The latter flow was associated with a collapse of the summit of the mountain. Flows from both sides of the mountain dammed small lakes. Cores were taken from the lakes in order to date the oldest organic sediment in them and to determine if there was basaltic tephra within the sediment that would indicate subsequent eruptions. A mid Holocene 14C age was determined on the southwest lake whereas an early Holocene age was determined on the base of the core from the northeast lake. There was no evidence of tephra falls from the mountain in either core. Consequently, the last eruption is thought to have occurred around the Pleistocene/Holocene boundary.

Stop 2-1 Pillow Point

This feature is located approximately 10 km downstream from Fort Selkirk. It is depicted in Figure 8. We may not land if river stage is too low. In that case, we will look at the section from the river. The continuous thickness of the pillow breccia indicates that the basalt was pouring into a lake of identical depth. Where subaerial basalt flows are interstratified with pillow breccia beds, rising lake levels may be inferred. Figure 8 shows the change in volcanic facies with direction down the Yukon River. The surface of the flow complex is devoid of drift with the exception of the downstream limit where the surface of the flow is less than 36 m above the Yukon River. Note the foreset bedding of the pillow breccia dipping towards the modern Yukon River channel. About 6 km downstream is a bed of boulder-supported gravel primarily composed of basalt. Boulders are commonly 1 m or larger in intermediate diameter. These may have been deposited by the breakout of the lava-dammed lake in the area of Pillow Point.

Stop 2-2 Fossil site

At this site, a basalt flow associated with the Ne Ch'e Ddhäwa eruptive period overlies a section of loess or resedimented loess which in turn overlies Triassic age greenstone. When this site was found in 1988 by Lionel Jackson and Brent Ward, a large mammal bone was visible at the top of the loess. This turned out to be the remains of a caribou (*Rangifer* sp.). A few rodent teeth were collected here and at the Cave site (Stop 2-3). Since then, John Storer has made a more extensive excavation and the list reads as follows:

Microsorex sp. /Shrew the size of the least shrew
Chiroptera, indeterminate /Bat
Spermophilus sp. /Ground squirrel
Predicrostonyx sp. /Ancestor of the collared lemming
Lemmus sp. /Brown lemming
Synaptomys sp. /Bog lemming
Phenacomys sp. /Heather vole (the oldest known?)
Allophaiomys deceitensis /Vole, possibly ancestral to some living *Microtus*.
Ochotona sp. /Pika
Leporidae, indeterminate /Rabbit, or more likely a hare
Mustela, new sp. /A new species the size of the least weasel
Rangifer sp. /Caribou

STOP 2-3 Cave site

This site is a few hundred metres upstream from Stop 2-2. THIS IS THE STEEPEST CLIMB OF THE FIELD TRIP SO BE CAREFUL WHILE ASCENDING AND DESCENDING! IT IS EASY TO KICK ROCKS DOWN ON OTHER PARTICIPANTS! The stratigraphy of the site is depicted in Fig. 5b. We will climb through outcrops of greenstone to encounter till from the older of the two pre-Reid glaciations. A till fabric and lithologies of stones are presented in Figs. 6 and 7. The till is succeeded by a gravel, presumably outwash gravel which fines upward into sand and fine sand. This is succeeded by silty sand, which contains the Fort Selkirk tephra. Several thin, impure beds of tephra, with gradational upper and lower contacts, occur above the tephra. These represent a reworking of the tephra. The fine sediment succession, which includes and overlies the tephra beds, contain silt intraclasts, scattered cross bedding, and soft sediments deformation structures including load and flame structures. These are indicative of a slack water fluvial or lacustrine sedimentary environments. A magnetic reversal is recorded in sediment overlying the Fort Selkirk tephra. Polarity changes from reversed to normal in an upward direction (Fig. 5b). As noted above, this reversal apparently represents the Gilsa Subchron. The entire fine interval was sampled for pollen but it was found to be barren. A few rodent teeth have been collected from the unit.

An indurated granular volcanic sediment overlying the silty sand interval was reported to be lapilli (Naeser et al. (1982) and Jackson et al (1996)). This was thought to have represented a tephra fall preceding the incursion of basalt flows into the area. However, this unit was reinterpreted as a fused pebble gravel and sandy pebble gravel deposit by one of the authors (Huscroft). The correction of this error was reported in Jackson (2000, errata). The predominantly basaltic composition of this sediment suggests that it was derived from nearby basalt flows. This unit is well exposed at the rear of the cave formed at the base of the basalt flows for which the site was named. This volcanoclastic unit locally contains carbonized wood.

Stop 2-4 Mushroom site

At this stop, we climb through the forest to the base of the basalt cliff to view gravel underlying columnar basalt. From the river, the radiating columns are apparent (‘war bonnet’ structure). They are surrounded by pillow tuff breccia. The radiating columns may indicate that we are close to the fissure from which the basalt was erupted. It is also possible that the eruption dammed the river and was partly underwater or that it was coincident with the older pre-Reid glaciation and occurred under ice. Definitive evidence is lacking.

The mushroom structure is overlain by the same succession of sediments as was seen at Stop 2-3 (Cave) with the exception of the till which was apparently eroded or not deposited at this site. The Fort Selkirk tephra also occurs here. The sediments are overlain by the upper flows seen at Stop 2-3.

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This concludes the field trip. We will take down our tents and board the riverboats for our return trip to Minto and road trip back to Whitehorse. The field trip leaders wish you an enjoyable CANQUA 2001 meeting.

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