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Late Cenozoic geology, Ancient Pacific Margin NATMAP Project, report 2: survey of placer-gravel lithology and exploration of glacial limits along the Yukon and Stewart rivers, Yukon Territory[1]

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Abstract: The lithology of placer gravels and indicators of glaciation were investigated in drainage basins near Mount Stewart, Thistle Mountain, and Selwyn Dome, west-central Yukon Territory. The composition of placer gravel indicates that mafic and felsic volcanic and subvolcanic rocks, unrecognized on existing bedrock geology maps, outcrop or suboutcrop in the area. Similar rocks host precious and base-metal deposits in the nearby Dawson Range. Ultramafic rocks are more extensive in the study area than previously thought. The presence of large erratic boulders suggests that the area may have been glaciated during the early Pleistocene.

Résumé : On a étudié la lithologie des graviers de placers et les indices de glaciation dans des bassins versants près du mont Stewart, du mont Thistle et du dôme Selwyn, dans le centre ouest du Territoire du Yukon. La composition des graviers de placers indique la présence dans la région, dans des affleurements ou des affleurements enfouis, de roches volcaniques mafiques et felsiques et de roches hypovolcaniques non encore reconnues sur les cartes de la géologie du substratum rocheux. Des roches similaires dans le chaînon Dawson voisin contiennent des gîtes de métaux communs et de métaux précieux. Les roches ultramafiques sont plus répandues dans la région à l'étude que ce que l'on croyait auparavant. La présence de gros blocs erratiques porte à croire que la région a peut-être été englacée au Pléistocène inférieur.

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[1] Contribution to the Ancient Pacific NATMAP Project

INTRODUCTION

Regional surficial geology mapping of the Stewart River map area (115-O, 115 N) and immediately adjacent areas of the Stevenson Ridge map area (115 J, K; Fig. 1) was initiated during the summer field season of 1999 as a part of the Geological Survey of Canada's new Ancient Pacific Margin NATMAP (National Mapping Program) Project. The activity centered on the upland lying between the Yukon and Stewart rivers. Selwyn Dome, Thistle Mountain, and Mount Stewart form the spine of this upland (Fig. 2). All or parts of 115 J/14, 15, 16 and 115-O/1, 2, 3 were covered during field operations.

Placer gold has been mined from Ballarat, Kirkman, Thistle, Barker, and Scroggie creeks since the end of the nineteenth century (McConnell, 1901; Cairns, 1916). The bedrock source of the gold in this region has never been identified and bedrock exploration has been relatively limited. Little natural bedrock exposure exists in the area and artificial exposures are confined to placer mines and associated roads and airstrips. Field work pursued the following five objectives: 1) ground-truthing of airphoto interpretation as a part of surficial geology mapping of the area; 2) extension of stratigraphy established for early Pleistocene sediments and interstratified basalts (Jackson et al., 1996) in the Carmacks map area (115 I) down the Yukon River valley into the Stewart River map area; 3) investigation of the stratigraphic setting of gold placers; 4) testing of the glacial limits previously mapped for the area; and 5) survey of rock types present within placer basins that host gold placers through sampling and identification of gravel-clast lithology.

This paper reports on preliminary results from work completed on the last two of these objectives. Results from the first three await various analyses or will be presented as open file maps in the near future.

GEOLOGICAL SETTING

Existing reconnaissance-scale geological mapping of the study area indicates that it is underlain by high-grade metamorphic rocks and intrusions or structurally emplaced granitic or ultramafic bodies (Bostock, 1942; Tempelman-Kluit, 1973). However, bedrock exposures are rare. Thick, residual colluvium covers hillsides and most ridge tops, and gravel and loess fills have accumulated in many valley bottoms. At one or more times during the late Pliocene or early Pleistocene, outlet glaciers from the Cordilleran Ice Sheet advanced down the Stewart and Yukon river valleys. This ice carried sedimentary clasts (e.g. chert, conglomerate, limestone, and orthoquartzite) from the central Yukon Territory and fresh olivine basalt from lava flows near Fort Selkirk into the study

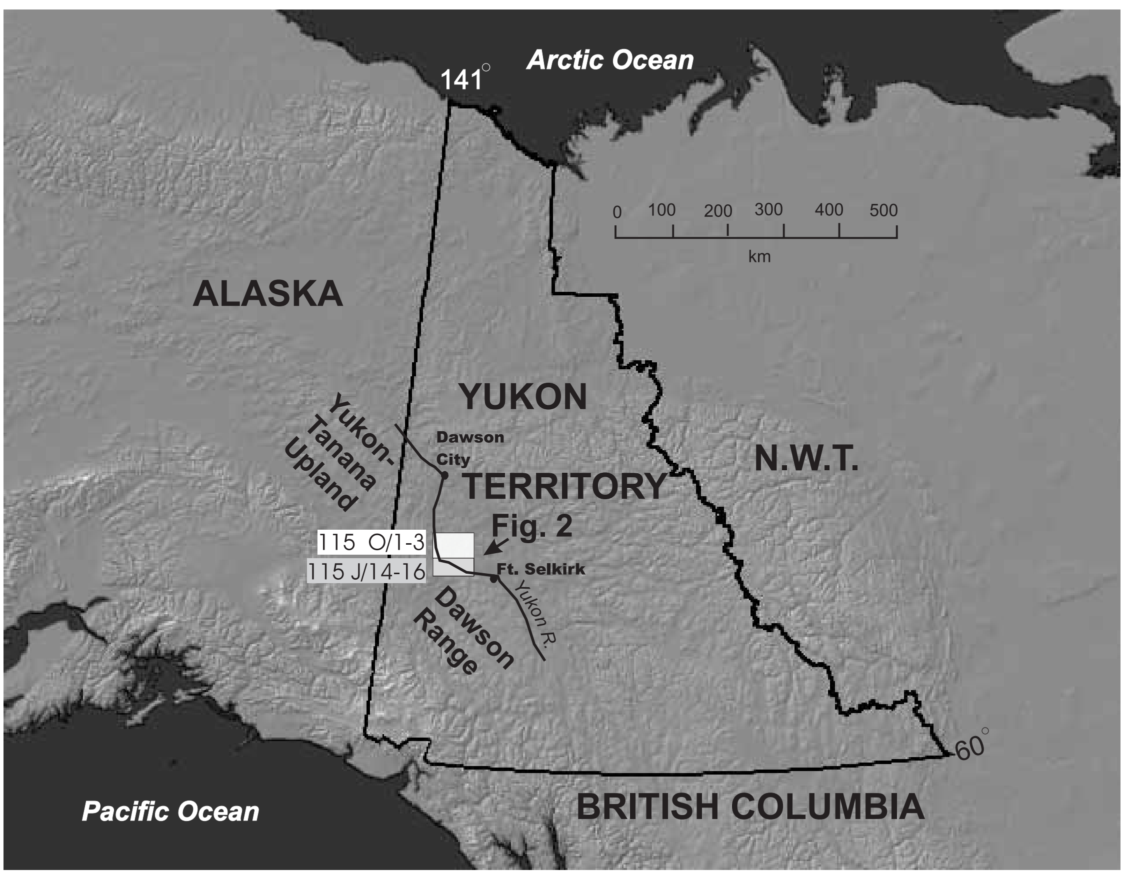

Figure 1. *Location of area investigated during 1999 field operations.*

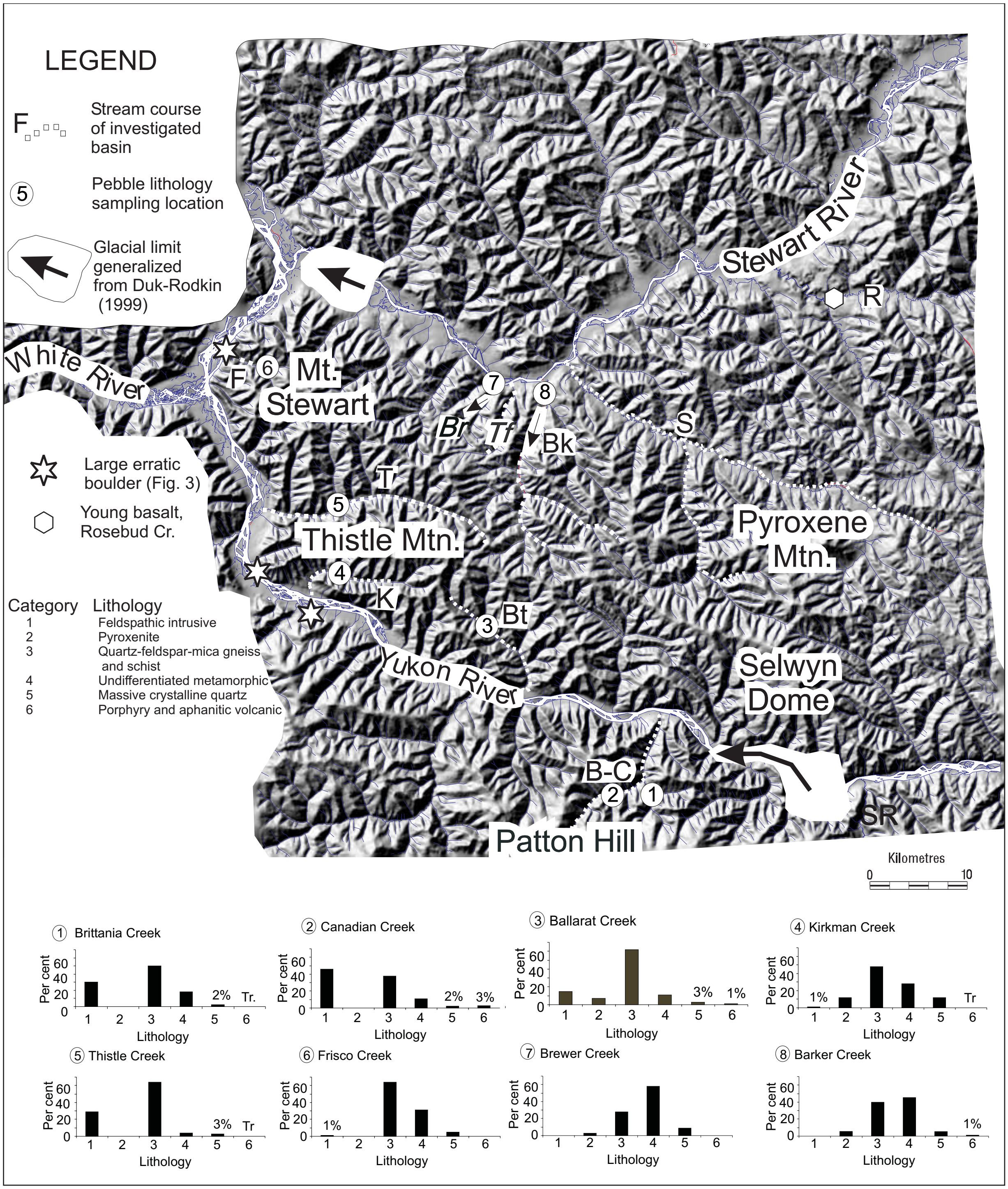

Figure 2. *Hillshade model generated from 1:50 000 scale National Topographic Data Base (NTDB) data showing locations of placer-producing streams, gravel samples, gravel clast lithology histograms, locations of erratics and young basalts, and glacial limits generalized from Duk-Rodkin (1999) for areas discussed in the text. The downstream limit of fresh olivine basalt in the Yukon River valley is immediately upstream of the area shown. F = Frisco Creek, Br = Brewer Creek, S = Scroggie Creek, R = Rosebud Creek, Bt = Ballarat Creek, B-C = Britannia and Canadian creeks, K = Kirkman Creek, T = Thistle Creek, SR = Selwyn River.*

area (Bostock, 1966; Hughes et al., 1969; Jackson, 1994, Fig. 13; Duk-Rodkin, 1999; Jackson, in press; Ward and Jackson, in press). With the exception of terrace gravels along the Yukon and Stewart river valleys, the occurrence of these rock types is indicative of past incursion of the Cordilleran Ice Sheet.

METHODOLOGY

Within drainage basins that have escaped incursion by the Cordilleran Ice Sheet, gravel clasts provide a sampling of the underlying bedrock. In order to investigate basin-wide rock types and the limits of glaciation, all available exposures of sedimentary fills were examined during the course of traverses by boat, all-terrain-vehicle, and foot. Samples consisting of 100 pebbles from 2 to 6 cm in intermediate diameter were collected from terraces along the Yukon and Stewart rivers and placer workings on Canadian, Ballarat, Kirkman, Thistle, Frisco, Brewer, and Barker creeks. In addition, gravel deposits were visually scanned for rock types present in trace quantities (1% or less). The gravel clast types were compared with the distribution of rock types shown on existing 1:250 000 scale geological maps and determined from larger scale mineral-deposit studies (Bower et al., 1995). Throughout the area, surficial deposits were examined for the presence of anomalously large erratic boulders.

RESULTS

Test of glacial limits —Yukon River valley

The basins of Canadian, Ballarat, Kirkman, Thistle, and Frisco creeks, all direct tributaries to Yukon River, lack any erratic rock types that would indicate past incursion of the Cordilleran Ice Sheet from the Yukon River valley (Fig. 2). Orthoquartzite, chert, chert-pebble conglomerate, and limestone are confined to thick terrace gravels along the Yukon River valley that are related to early Pleistocene, pre-Reid glaciations (Jackson et al., 1996): terrace levels rise towards the glacial limits mapped by Duk-Rodkin (1999) in the area of the confluence of the Selwyn and Yukon rivers (Fig. 2). They are also capped by the early to middle Pleistocene Wounded Moose paleosol (Smith et al., 1986; Tarnocai and Schweger, 1991). During examinations of cliff-bank exposures of these pre-Reid gravels, large boulders were found between the mouths of Kirkman and Frisco creeks. The surrounding gravel ranges in size from pebbles to cobbles. A few of the many boulders noted in this area are described in Table 1. Some have been eroded from terrace gravel and are found along the foot of cliff banks. Many others are found in place within the terrace gravels. The surrounding gravel deposits commonly contain chert, basalt, and other rock types from sedimentary terrain in the east-central Yukon Territory. The gneiss boulders found in the Kirkman Creek area are similar to the Pelly Gneiss, which outcrops a minimum of 6 km upvalley (Tempelman-Kluit, 1973). The erratic designation for these boulders is provisional because no underlying bedrock is exposed near their occurrences. However, even if the gravel fill were underlain by gneissic bedrock, the large sizes of these boulders compared with surrounding sandy to cobble gravel requires an explanation. Blocks of greenstone and fresh, vesicular olivine basalt (Table 1 and Fig. 3) are definitely erratics. The nearest bedrock outcrops are 70 km upstream along the Yukon River.

Test of glacial limits — Stewart River valley

In the Stewart River valley, Duk-Rodkin (1999) delineated the limits of Cordilleran Ice Sheet glaciation at the confluence of the Yukon and Stewart rivers (Fig. 2). The Cordilleran Ice Sheet was shown to have pressed up the valleys of Barker and

Table 1. Location and description of erratic boulders.

Location (UTM zone 7: easting, northing)	**Dimensions** (m)	**Shape and lithology**	**Minimum distance to source** (km)	**Local bedrock lithology**	**Comments**
cutbank exposure in terrace, left bank of the Yukon River opposite the mouth of Kirkman Creek (582402, 6984368)	2x3x>1	subangular quart-mica migmatite with ptygmatically folded quartzose bands or veins; mineral grains range from 0.5 to 3 mm (Fig. 3a)	6?	schist?	Poor exposure of local bedrock makes identification as erratic lithology uncertain. Tentatively identified as Pelly Gneiss. The large size of the block rules out fluvial transportation. The lack of adjacent high cliffs or rugged terrain within many kilometres precludes a rockfall origin.
50 m downstream	1.3x1.1x1.67	subrounded augen gneiss (Fig. 3b).	6?	schist?	as above
same location as above, but vertically above	0.6x0.3x>0.3	rounded olivine basalt hyaloclastite	70	schist?	Basaltic hyaloclastite extensively outcrops in the Fort Selkirk area. No known young basalt is present along the Yukon River less than 70 km to the east.
50 m downstream from above	1.3x0.9x0.6	as above	6?	schist?	as above
50 m downstream from above	1.5x1x0.7	as above	6?	schist?	as above
cutbank exposure in gravel terrace, northern bank of the Yukon River, 5 km below the mouth of Kirkman Creek (575417, 6989741)	2x1x0.6	subangular vesicular olivine basalt (Fig. 3b.)	115	schist?	Easily identified as originating from the early Pleistocene Selkirk volcanic rocks. No flows are known west of longitude 138°W.
same area as above (575420, 689740).	1.5	subangular, pyramidal greenstone	70	schist?	Boulder has one polished surface covering 50 cm^2. Subparallel striations. One nailhead striation 10 cm long.
mouth of Frisco Creek (573437, 7010656)	0.8x0.5x0.6	angular vesicular olivine basalt	90	schist	Angular boulder was excavated during placer-mine operations.

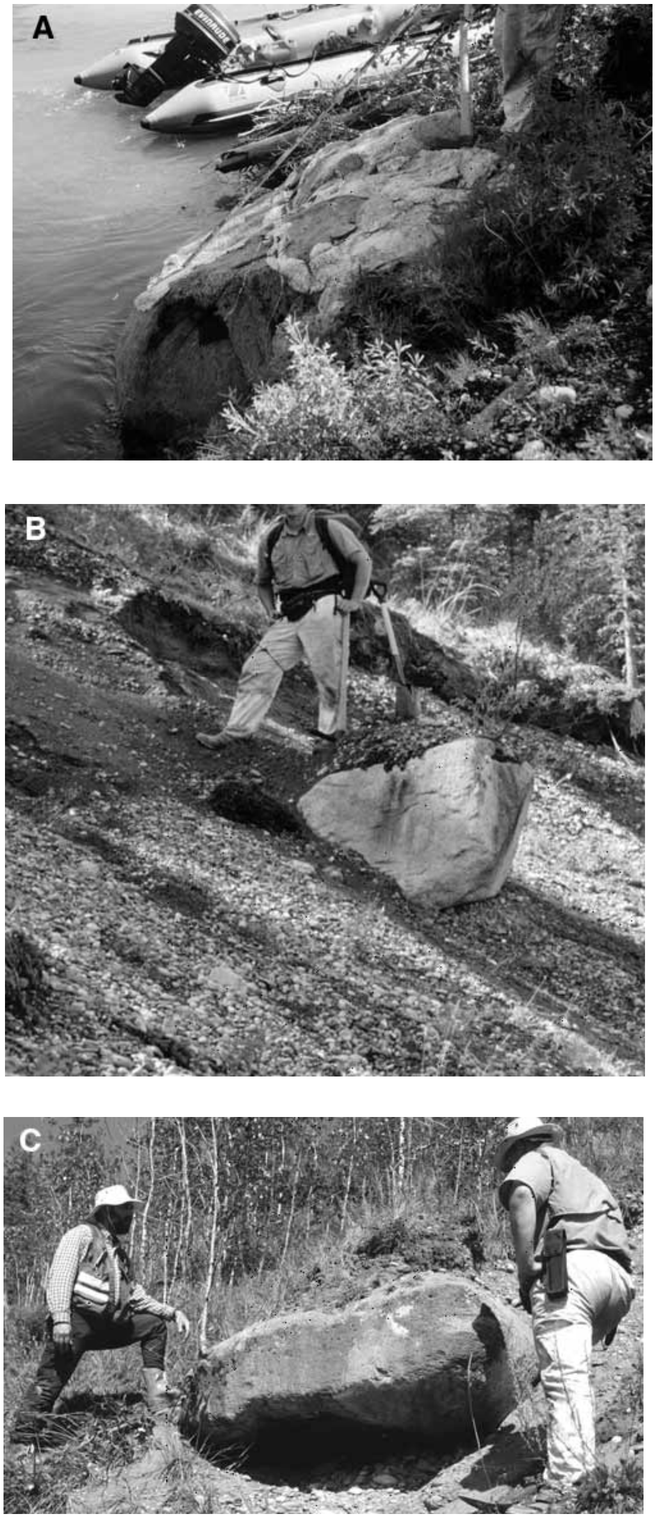

Figure 3. *Large boulders found in glaciofluvial outwash gravel.* ***A*** *= quartz-mica gneiss with ptygmatically folded quartzose bands or veins;* ***B*** *= augen gneis;* ***C*** *= fresh vesicular olivine basalt*

Brewer creeks (Fig. 2). To test the accuracy of these glacial limits, gravel was sampled along the lower reaches of Barker and Brewer creeks. Rocks exotic to the predominantly schistose Barker Creek basin (including abundant chert clasts) were found only in bench gravels at the mouth of Barker Creek at heights of up to about 34 m above Stewart River. Measurements of the imbrication of tabular clasts in these chert-bearing gravels indicate deposition by stream flow from the northeast down the Stewart River valley. This gravel changes facies within 2 km upstream along Barker Creek to a gravel containing no rock types from terrains to the east. Measurements of clast imbrication indicate that this gravel was deposited from the east to southeast. Mark Becker, a placer miner working claims in this area, noted that the facies change between chert-bearing and nonchert-bearing gravel is coincident with a change from nonproductive (chert-bearing) to auriferous (no chert) gravels along the historically placer-mined benches on Barker Creek (M. Becker, pers. comm., 1999). During traverses of the Brewer Creek basin northwest of Barker Creek, no erratic rock types were found in placer gravel along valley bottoms and along the drainage divide with lower Telford Creek.

Gravel-clast lithology as an indicator of basin bedrock lithology

The locations of pebble samples taken from basins tributary to the Yukon and Stewart rivers are shown in Figure 2 along with histograms displaying distributions of clast types. A comparison with regional bedrock (Bostock, 1942; Tempelman-Kluit, 1973) and mineral-deposit maps (Bower et al., 1995) reveals that sampled clasts are largely compatible with previously recognized bedrock types. Discrepancies between sampled and expected local rock types are due to the presence of ultramafic, volcanic, and subvolcanic clasts. Pyroxenite pebbles were retrieved from gravels in Ballarat, Brewer, and Barker creeks. Aphanitic volcanic clasts of felsic to mafic composition were encountered in Ballarat, Kirkman, Thistle, and Barker creeks. Feldspar-porphyry pebbles were found in Thistle, Barker, Canadian, and Britannia creeks.

DISCUSSION

Implications of large erratic boulders

Three hypotheses, to be tested during future field seasons, are proposed to explain the discovery of many large erratic blocks in the Yukon River valley up to 60 km beyond mapped glacial limits (Duk-Rodkin, 1999):

1. The erratics were not deposited directly by ice but were laid down during a massive glacial outburst flood (jökulhlaup).
2. The erratics were transported by icebergs across a glacial lake.

3. The erratics were transported by glacial ice during one or more glaciations with glacial extents that surpassed the limits recognized by Duk-Rodkin (1999).

With respect to hypothesis 1, jökulhlaups in confined bedrock valleys leave continuous beds of large boulders that can be traced for many kilometres (e.g. Birkeland, 1968; Lye et al., 1990). No such boulder beds were observed in pre-Reid outwash gravels along the Yukon River valley between Kirkman Creek and the mapped glacial limit upstream. The large erratics are almost entirely restricted to the Yukon River valley reach between Kirkman and Thistle creeks. However, it should be noted that outwash gravels are rarely exposed from river level to terrace surfaces in the study area or down to the depositional contact with underlying bedrock.

With respect to hypothesis 2, the presence of a large lake (Glacial Lake Yukon) filling much of the Yukon River drainage basin beyond the glacial limit has been inferred by Duk-Rodkin (1999). This lake would have been comparable in size to the network of large, glacially dammed lakes that existed in the interior of British Columbia at the end of the last ice age (Fulton, 1967). The British Columbia glacial lakes received immense volumes of glaciolacustrine sediments (Fulton, 1965; Eyles and Clague, 1991). No evidence of such a lake in the form of relict glaciolacustrine sediments was observed within the study area (Fig. 2). Furthermore, the erratics are found in coarse gravel and not in fine sand and silt, as would be expected if they had ben deposited in a glacial lake basin.

With respect to hypothesis 3, the chronology of Jackson et al. (1996) and Jackson (in press) in the Fort Selkirk area indicates that up to 10^6 years have elapsed since the last pre-Reid glaciation and perhaps another 0.5 x 10^6 years since the penultimate pre-Reid glaciation. Furthermore, geomorphic evidence in the area suggests that at least one additional pre-Reid glaciation may have predated these two during the early Pleistocene or late Tertiary. This even earlier event may have caused the regional reversal of the flow of the Yukon River (Jackson, in press). Extensive regional erosion almost certainly occurred over the periods between and since the pre-Reid glaciations. One million years or more of erosion would be expected to eliminate all but the largest scale glacial erosional features. For example, in north-central Alaska, evidence of the oldest, perhaps late Tertiary, glacial advance from the Brooks Range (Gunsight Mountain Glaciation; Hamilton, 1986), consists predominately of erratics. Closer to the study area in the Dawson Range (Fig. 1), which was glaciated during the last pre-Reid glaciation, meltwater channels have been totally buried by colluvial sedimentation, leaving a landscape that appears unglaciated (Lebarge, 1995; Jackson et al., in press).

If the Cordilleran Ice Sheet extended beyond the limits shown by Duk-Rodkin (1999) in the Yukon River valley and reached those defined by her in the Stewart River valley (Fig. 2), the lack of erratics from the east-central Yukon Territory in tributary valleys such as those of Ballarat, Kirkman, Barker and Brewer creeks must be accounted for. A possible explanation is that the high terrain of Thistle Mountain (elevation 1489 m), Selwyn Dome (1573 m), and the uplands collectively indicated as 'Patton Hill' on Figure 2 (elevations up to 1795 m) supported ice caps and valley glaciers during one or more of the pre-Reid glaciations. This would agree with the record of early Pleistocene and presumably pre-Reid equivalent glaciation in the Yukon-Tanana upland of adjacent Alaska (Fig. 1). Weber (1986) suggests that glaciers may have formed on all mountains above 900 m during the early Pleistocene Charlie River Glaciation in that region. If so, then ice caps within the study area would have fed valley glaciers that joined trunk glaciers from the Cordilleran Ice Sheet in the Yukon and Stewart river valleys. The valley glaciers would have prevented erratic rock types from entering tributary valleys.

Implications for regional bedrock geology

Basins with gravels that lack erratic sedimentary rocks and or fresh olivine basalt, clearly have escaped past incursions of the Cordilleran Ice Sheet. Therefore, clast lithology represents a sampling of the bedrock underlying these basins. Feldspar-porphyry pebbles in gravels along Thistle and Barker creeks are similar to Carmacks Group subvolcanic rocks in the Dawson Range. Furthermore, aphanitic volcanic clasts found in Ballarat, Kirkman, Thistle, and Barker creeks are similar to volcanic rocks of the Mount Nansen and Carmacks groups. Both these groups form prominent, northwest-trending dyke swarms across the Dawson Range (Tempelman-Kluit, 1973). The occurrence of these volcanic and subvolcanic clasts may indicate an extension of these dykes into the study area.

Finally, pyroxenite pebbles were found in Ballarat, Brewer and Barker creek basins. Pyroxenite has not been mapped within them. This indicates that the ultramafic body composing Pyroxene Mountain is more extensive than was previously mapped or is part of a trend of many individual bodies.

ECONOMIC IMPLICATIONS

To date, economic lode gold deposits have been found only in the Patton Hill area at the head of Canadian and Britannia creeks along the southern margin of study area. Bostock (1936) first noted a close association between placer gold, lode gold, and felsic intrusives in the Dawson Range. More recently, a genetic relationship between Carmacks magmatism, alteration, and gold mineralization in the form of precious and base-metal veins and gold-copper porphyries has been recognized (Smuk et al., 1997). Within the Casino porphyry deposit on Patton Hill (Fig. 2) copper, gold, and molybdenum mineralization is genetically related to a microbreccia pipe consisting of a plagioclase porphyritic intrusion (Bower et al., 1995). If the association of gold with porphyritic intrusions found in the Dawson Range persists into the study area, then the presence of porphyry clasts in placer gravels would indicate that these placer-producing basins constitute potential targets for lode-gold exploration.

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