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Preliminary results of field mapping, GIS spatial analysis, and major-element geochemistry, Ruby Mountain volcano, Atlin volcanic district, northwestern British Columbia[1]

B.R. Edwards and A. Bye

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Abstract: We present results from fieldwork, GIS spatial analysis, and major-element whole-rock geochemistry completed between July 2000 and May 2002 for the Ruby Mountain volcano, in the northwestern Atlin map area (NTS 104 N/11). The map of the distribution of lava flows, tephra, and volcanic breccia at the Ruby Mountain volcano enables the use of the Spatial Analyst tool in ArcView® 3.2 to calculate the surface areas of the lava flows and, subsequently, to estimate flow volumes. Preliminary analysis of whole-rock major-element results for 10 samples of olivine-porphyritic volcanic rocks, including samples from the Ruby Mountain volcano (8), the Ruby Creek lava flow (1), and the Cracker Creek cone (1), show that all are alkaline and vary in composition from basalt to hawaiite to basanite.

Résumé : En relation avec le volcan du mont Ruby, situé dans la partie nord-ouest de la région cartographique d'Atlin (SNRC 104N/11), nous présentons les résultats de travaux complétés entre juillet 2000 et mai 2002, qui se rapportent à des levés sur le terrain, à une analyse spatiale par SIG et à la géochimie des éléments majeurs sur roche totale. La représentation cartographique de la répartition des coulées de lave, des tephras et des brèches volcaniques au volcan du mont Ruby permet d'utiliser l'outil Spatial Analyst du logiciel ArcView® version 3.2 pour le calcul de la superficie des coulées de lave puis d'en estimer le volume. Les résultats préliminaires de l'analyse géochimique des éléments majeurs sur roche totale de 10 échantillons de roches volcaniques à phénocristaux d'olivine, incluant des échantillons du volcan du mont Ruby (8), d'une coulée de lave au ruisseau Ruby (1) et du cône du ruisseau Cracker (1), révèlent que toutes ces roches présentent des affinités alcalines et que leur composition varie du basalte à la basanite, en passant par l'hawaiite.

[1] Contribution to the Atlin Targeted Geoscience Initiative

INTRODUCTION

The Ruby Mountain volcano is located approximately 25 km east of the town of Atlin and 5 km north of Surprise Lake, on the west side of the Ruby Creek drainage (Atlin map sheet NTS 104 N; centre UTM 591650E/6618250N; base at 1000 m above sea level) (Fig. 1a). It is the largest volcano in the Surprise Lake volcanic field (Edwards et al., 2003), which is part of the Atlin volcanic district of the Northern Cordilleran volcanic province (Edwards and Russell, 2000). The Ruby Mountain volcano is one of three volcanic features within the Ruby Creek drainage; the Cracker Creek cone is located directly east of Ruby Mountain, at the head of Cracker Creek (Fig. 1a), and the Ruby Creek lava flow extends along Ruby Creek for approximately 3 km. The Ruby Mountain volcano is accessible by approximately 26 km of gravel roads east of Atlin, British Columbia, and can be reached by four-wheel-drive vehicle from mining roads along either Boulder Creek or Ruby Creek (Fig. 1a). Its summit is 1895 m above sea level (Fig. 1b).

Previous work at Ruby Mountain includes general mapping of volcanic units by Aitken (1959), geochemical analyses by Nicholls et al. (1982) and Abraham et al. (2001), and general descriptions of geomorphic (Levson, 1992) and geological features (Edwards et al., 1996).

We spent 10 days during July 2000 mapping volcanic units at Ruby Mountain and Ruby Creek at 1:20 000 scale (Fig. 1b) and collecting samples for petrographic and geochemical study. We also visited active placer-mining operations along Ruby Creek and collected geochemical samples from the Ruby Creek lava flow and the Cracker Creek tephra cone. Field maps were digitized using ArcView GIS and used to create Triangulated Irregular Network (TIN) models for quantitative spatial analysis of the mapped volcanic deposits. Our preliminary estimates indicate that the edifice has a maximum surface area of 3.4 km^2 and a maximum volume of 0.59 km^3. Results from our preliminary petrographic studies and whole-rock major-element analyses are consistent with previous work and show that the rocks at Ruby Mountain are alkaline basalt, hawaiite, and possibly basanite.

FIELD MAPPING AND UNIT DESCRIPTION

New field mapping focused predominantly on the largest volcanic construct in the Surprise Lake volcanic field, the Ruby Mountain volcano, where we delineated a minimum of four lava flows, airfall deposits, volcanic breccia, landslide deposits, and a rock glacier (Fig. 1b). We also briefly visited the Cracker Creek cone and several sites along the Ruby Creek lava flow, partly delineating its northward extent (Fig. 1b).

Ruby Mountain volcano

Aitken (1959) very accurately described the Ruby Mountain volcano as the "battered remains" of a volcano. As viewed from the air, the summit crater of Ruby Mountain, which rises 695 m from the valley floor of Ruby Creek to an elevation of 1895 m, appears to have been modified by landslides on its eastern (Fig. 2, 3b) and northern (Fig. 2, 3c) flanks; it currently hosts a rock glacier on its northwestern flank (Fig. 2, 3d). Its distinctly sculpted form, nearly resembling a glacial horn, is evident when viewed from the eastern side of Ruby Creek (Fig. 3a). Although no glacial till or striae were observed on the upper flanks of the summit, a cirque-like structure appears to be preserved along the ridge immediately west of the summit, consistent with the current position of the rock glacier. The northern side of Ruby Mountain may also have hosted a small cirque glacier given its present geometry (Fig. 2).

The volcano was built mainly upon alaskite of the Surprise Lake batholith (Fig. 1b), but abuts metasedimentary rocks of the Cache Creek Group along its western flank (Fig. 1b; Aitken, 1959; Bloodgood et al., 1989).

The upper part of the volcano's eastern and northern flanks (Fig. 3b, c) is underlain by a thick (~15 m) unit of columnar-jointed lava, above which is mainly loose, lapilli- to bomb-sized scoriaceous tephra. As noted by Edwards et al. (1996), the soil-covered floor of the crater is covered with periglacial frost polygons.

Mixed tephra and breccia

Most exposed rocks on Ruby Mountain are brown-red pyroclastic deposits of bombs and scoriaceous lapilli (Edwards et al., 1996; Fig. 1b). Crude bedding is preserved locally (Fig. 3e), with the smaller pyroclasts approaching ash size (<2 mm) (Fig. 3f). Spindle bombs are rare close to the summit; they are commonly up to >30 cm long and rarely >2 m long (Edwards et al., 1996). Pyroclasts locally contain fragments of white vesiculated blobs, which appear to be slightly to totally melted fragments of granite (Fig. 3f, h). Some xenoliths are up to 1 m in maximum dimension (Edwards et al., 1996).

Mixed lava and tephra

Immediately underlying the summit on the east and north sides, tephra is interlayered with lenses of massive lava (Fig. 1b, 3b, c).

Lava flows

Four lava-flow remnants occur on the northern, northeastern, eastern, and southeastern flanks of the volcano (Fig. 1b). Along the eastern flanks of Ruby Mountain, the lava flows are as thin as 90 cm and at one location, a basal breccia separates two lava flows. On the lower northern slopes of the volcano, one of the lava flows is about 10 m thick. The lava flows commonly exhibit vertical columnar joints and contain olivine phenocrysts and white feldspar fragments, possibly derived from granitic basement rocks. Peridotite xenoliths are uncommon, are rarely greater than 2 cm in size, and are found predominantly in lava flows on the northern flank of the volcano.

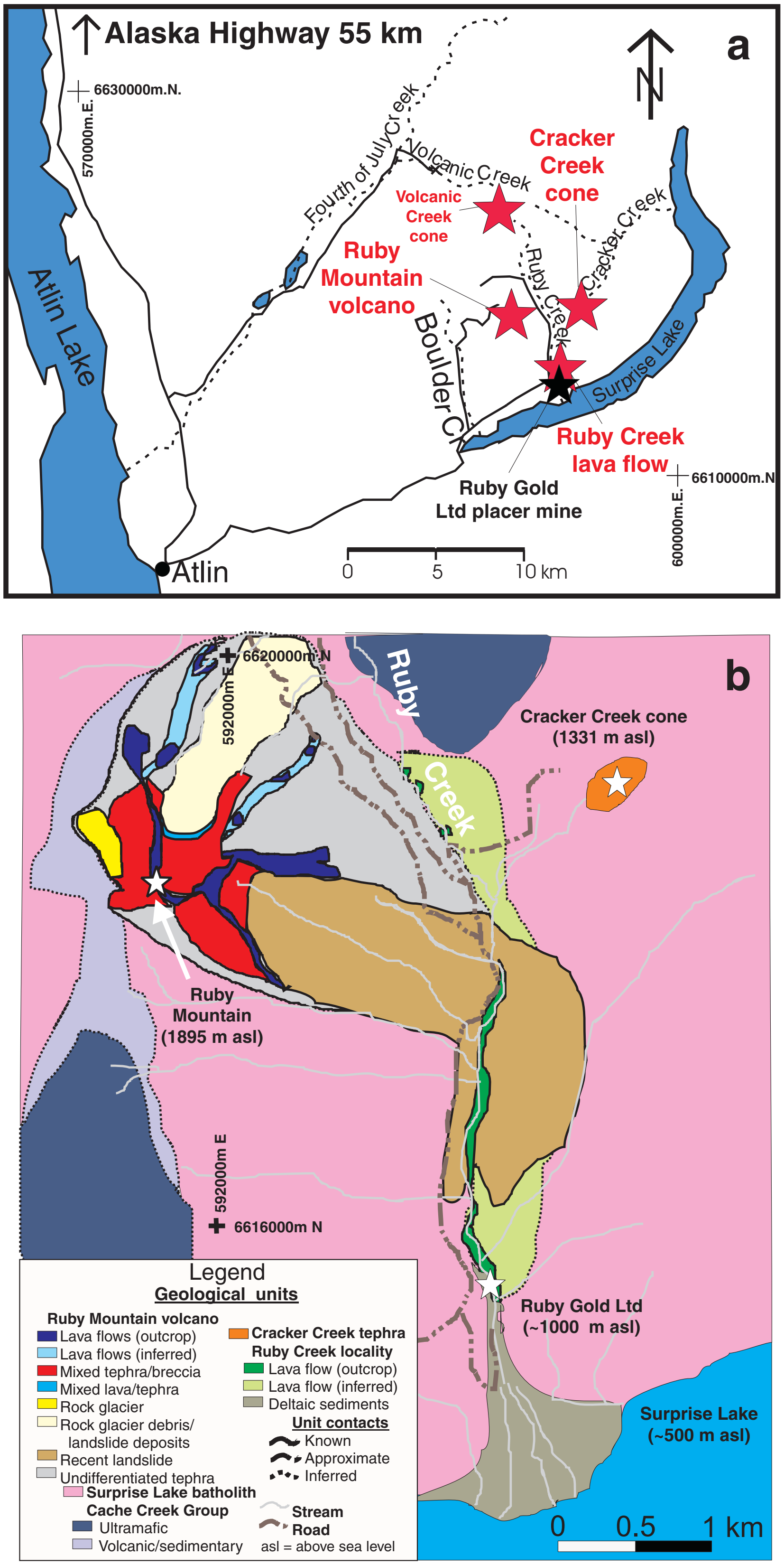

Figure 1. *a) Location of volcanic features, represented by red stars, in the Surprise Lake volcanic field northeast of Atlin, British Columbia.* ***b****) Detailed geological map of the area around Ruby Mountain volcano. Geology was compiled on a 1:20 000 TRIM map; bedrock distribution* from *Bloodgood and Bellefontaine (1990).*

Landslide deposits

Landslides have played an important role in reshaping the morphology of Ruby Mountain (Levson, 1992; Edwards et al., 1996). The most recent landslide, on the eastern flanks of the mountain (Fig. 2, 3b), crossed Ruby Creek and transported boulders of bedded tephra to its western edge (Fig. 3g). The eastern landslide was recent enough that trees growing on the deposit are distinctly younger than those immediately south of the deposit. The area immediately north of the summit crater (Fig. 2) is loose tephra that forms mounds, producing a lobate, hummocky morphology. Although this area also appears to have hosted a small cirque glacier, the hummocky terrain could also have formed from a large mass-wasting event.

Cracker Creek tephra cone

The Cracker Creek cone is a small tephra cone composed of partly indurated, scoriaceous lapilli. It is located at the head of Cracker Creek, slightly northeast of and across the Ruby Creek drainage from Ruby Mountain (Fig. 1b, 2, 4a). It has maintained a distinctive, presumably primary volcanic morphology, even though it appears to be partly overlain by a lateral moraine along the east edge of the Ruby Creek drainage and has granitic glacial erratics scattered atop its summit. It is about 50 m high and has a radius slightly greater than 350 m at its base. The site was visited briefly to collect samples for geochemical comparisons with samples from Ruby Mountain and Ruby Creek.

Ruby Creek lava flow

A locally thick (20–30 m), columnar-jointed (Fig. 4c, d), olivine-porphyritic lava flow extends for at least 3 km along Ruby Creek (Fig. 1b). It and the underlying gold-bearing placer deposits have been described briefly by Aitken (1959) and Levson (1992) and are currently being mined by Ruby Gold Limited (Wojdak, 2002). The Ruby Creek lava flow is the longest and thickest lava flow in the Surprise Lake volcanic field. Although various authors have ascribed it to the Cracker Creek cone (Aitken, 1959) and to the Ruby Mountain volcano (Edwards et al., 1996), we could not resolve its origin unambiguously in the field. We found previously recognized isolated outcrops farther

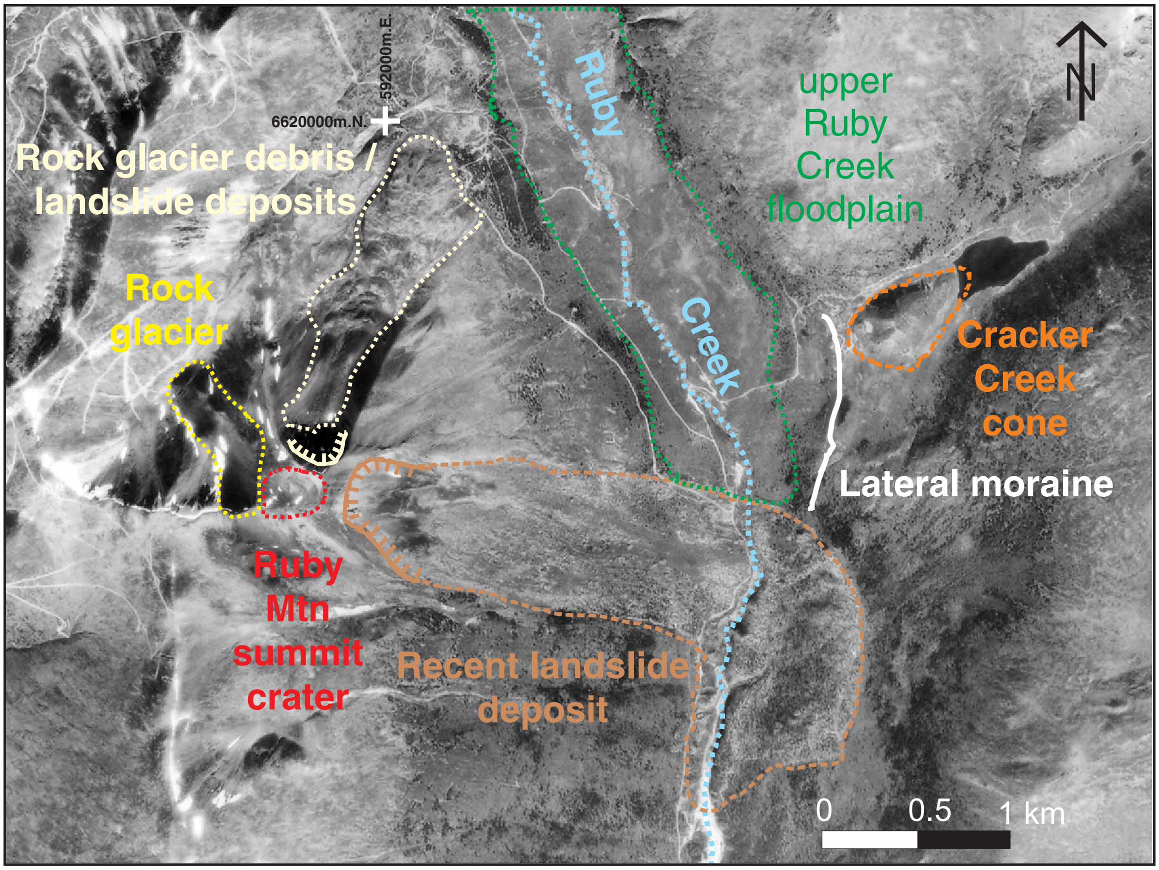

Figure 2. *Enlarged section of aerial photograph BC88063 No. 216 showing the distribution of landslide deposits, the rock glacier, the summit of Ruby Mountain volcano, and the Cracker Creek cone.*

upstream, but could not identify the vent responsible for the flow. The lava has been dated (K-Ar, whole rock) at 540 ka ± 200 ka BP (Mortensen, 1992).

Sedimentary deposits underlie and overlie the lava flow along much of its length (Fig. 4b, c, d). About 1 km downstream from the northernmost outcrops, the lava flow is overlain by glacial till (Fig. 4b) and deposits from the eastern landslide. Farther downstream, coarsely bedded gravel and sand deposits directly overlie the lava flow (Fig. 4c). Levson (1992) described clasts of basalt and tephra in sedimentary material immediately beneath the lava, some of which he ascribed to local interaction between lava and water; we did observe the volcanogenic sedimentary material beneath the lava, but found no direct evidence of subaqueous eruption. The well rounded gravel beneath the lava locally contains charcoal (Fig. 4e).

ARCVIEW GIS

We used the ArcView 3.2 GIS package to create a digital elevation model for Ruby Mountain in order to facilitate compilation of our geological mapping and to attempt to quantify the surface areas and volumes of the deposits mapped at Ruby Mountain. Three-dimensional models of Ruby Mountain volcano were created using ArcView ArcTIN so that surface areas and volumes for specific units could be estimated. These models are created using a Triangulated Irregular Network (TIN) in which sets of points with x, y, and z values are connected to form triangles that mimic the topographic surface. Where no x, y, and z values are located, the TIN module interpolates to find the z value (Hastings et al., 1998). Calculations of the surface area and volume of the volcano and lava flows were made using the Spatial Analyst extension of ArcView GIS. Using this feature, the volume for the main edifice was estimated by creating a three-dimensional feature whose lowest elevation defines the edge of the horizontal plane bounding the lower surface of the unit and whose highest elevations mark the uppermost contours bounding the upper surface of the lava. This volume estimate is considered to be a maximum volume for the current edifice, because a horizontal planar surface introduces a large amount of error. However, post-eruption erosion has also removed a substantial volume from the edifice. Volumes for the landslide deposit were calculated by multiplying the surface area determined with ArcView by an estimated average thickness of 20 m for the deposit, which is probably a maximum thickness. Volumes for lava flows were estimated with ArcView surface areas and an assumed average thickness of 5 m, also probably a maximum thickness.

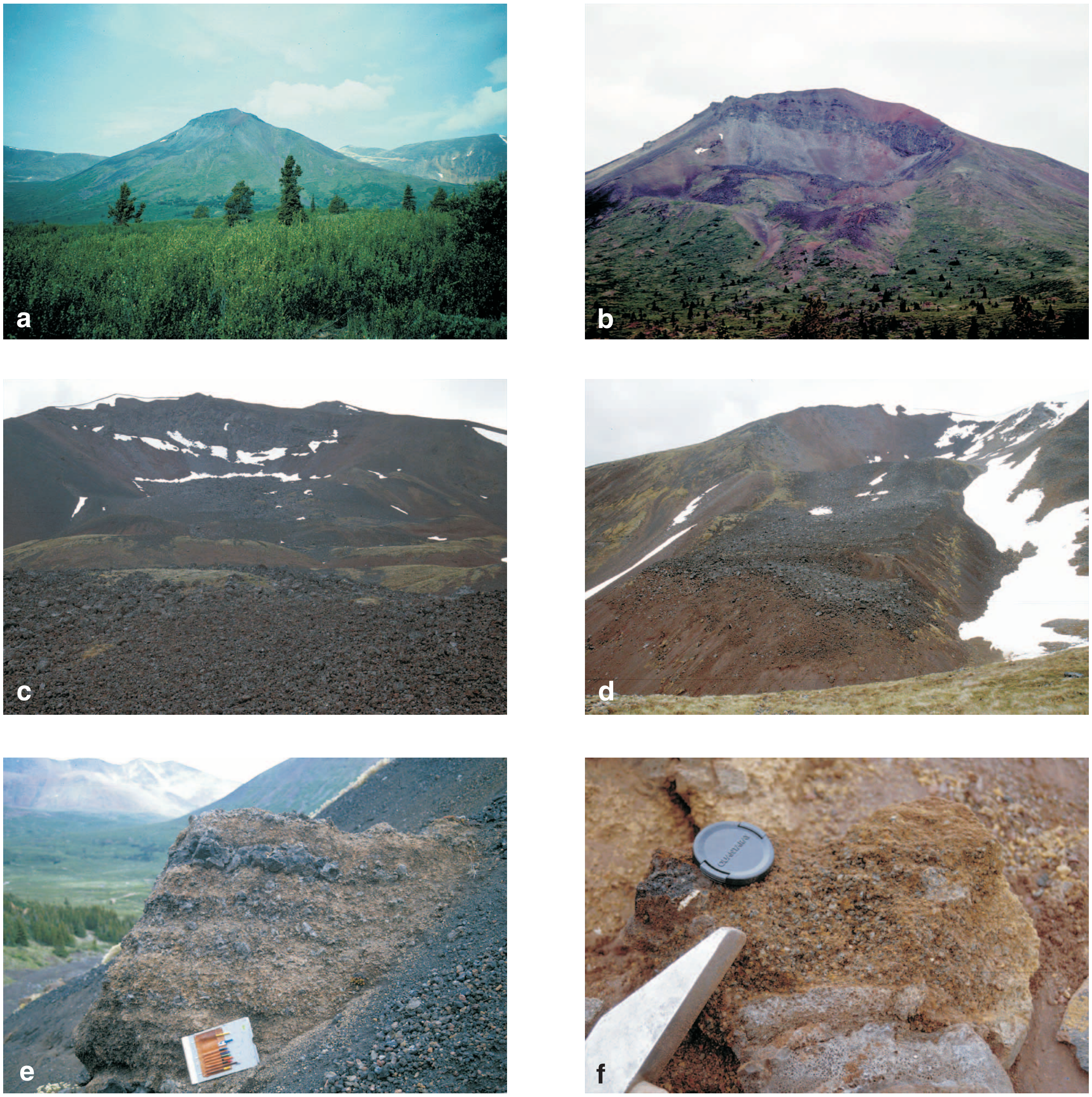

Figure 3. *Nature of various features and deposits at Ruby Mountain volcano.* ***a****) View to the west from near the Cracker Creek cone of the eastern flank of Ruby Mountain. The cone rises about 695 m from the valley floor.* ***b****) Detailed view to the west of the eastern flank of Ruby Mountain, showing the landslide scarp of the eastern landslide deposit, the forested hummocky terrain on the landslide surface, and the dark grey lava flows immediately below the summit. The change in elevation from the forested slopes to the summit is about 500 m.* ***c****) View south to the northern side of the summit of Ruby Mountain. Hummocky terrain is in the foreground. The height from the foreground to the mountain summit is about 300 m.* ***d****) View to the east of the rock glacier. The nose of the rock glacier is about 10 m thick.* ***e****) View to the east of bedded tephra on the northern flank of Ruby Mountain; the clipboard is 40 cm long.* ***f****) Detail of glassy, loosely welded lapilli. Note the small white xenolith below and to the left of the lens cap, which is 7 cm in diameter.*

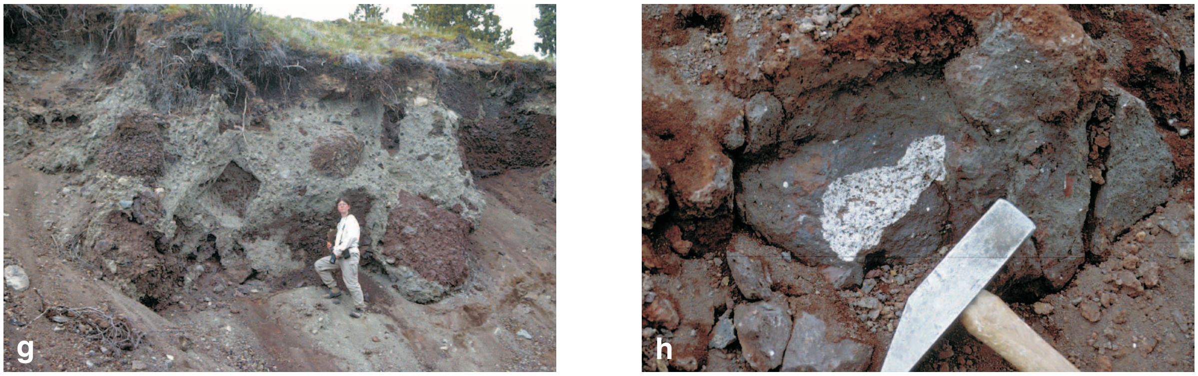

Figure 3. ***g****) Eastern landslide deposit along the west bank of Ruby Creek with rotated blocks of bedded, moderately welded lapilli. The person for scale is about 1.5 m.* ***h****) Large, partly melted white xenolith in tephra block. The portion of the hammer head is 12 cm long.*

Our preliminary results (Table 1) indicate that the Ruby Mountain volcano has a volume of no more than 0.59 km^3 and a surface area of 3.4 km^2. Mapped lava flows only cover about 15 per cent of the surface of the volcano. The estimated surface area and volume of the eastern landslide deposit indicates that a potentially substantial volume of the volcano, as much as 10 per cent, has been removed from the main edifice by mass wasting.

Table 1. Calculated surface areas and estimated volumes for various geological features at Ruby Mountain volcano.

Feature	Surface area (km^2)	Volume (km^3)
Ruby Mountain volcano	3.4	0.59
Total lava flows	0.58	2.9×10^{-2}
Landslide	2.9	0.06
Rock glacier (north)	0.14	1.0×10^{-2}

PRELIMINARY PETROGRAPHY

All lava samples examined in thin section are holocrystalline and olivine porphyritic with clinopyroxene microphenocrysts (less than 0.3 mm) and plagioclase, clinopyroxene, and opaque grains in the groundmass. Olivine crystals are euhedral to subhedral and rarely show subgrain development. Clinopyroxene microphenocrysts are typically euhedral and equant. Plagioclase laths in the groundmass are up to 0.03 mm long. Isolated larger grains of anhedral quartz and feldspar may be xenocrysts.

MAJOR-ELEMENT GEOCHEMISTRY

Eight samples of olivine-porphyritic lava from the Ruby Mountain volcano, along with one sample each from the Cracker Creek cone and the Ruby Creek lava flow, were sent to McGill University analytical laboratories for whole-rock major-element analyses (Table 2). The samples from Ruby Mountain all plot above the alkaline-subalkaline division of Irvine and Baragar (1974) and are classified as hawaiite and basanite (LeBas et al., 1986; Fig. 5). The classification is consistent with the olivine-dominated mineral assemblage seen in thin section. The sample from the Ruby Creek lava flow plots within the middle of the field for samples from the Ruby Mountain volcano (Fig. 5). However, the sample from the Cracker Creek cone is slightly displaced to lower values of total alkalis (Fig. 5), has the lowest value of TiO_2 (2.09 wt. %), and the highest value of MgO (10.0 wt. %) compared to the other nine samples (Table 2). All samples from the Surprise Lake volcanic field are enriched in alkalis compared to samples with similar values of SiO_2 from the other deposits in the Atlin volcanic district (Fig. 5).

ONGOING STUDIES

We are continuing to work on developing a physical and chemical model for the eruption history and petrological evolution of the Ruby Mountain volcano and the other volcanic centres in the Surprise Lake volcanic field (Edwards et al., 2003; A. McCarthy and B.R. Edwards, work in progress, 2002). We are currently awaiting complementary trace-element analyses for the ten geochemical samples in Table 2 and are in the process of conducting more detailed investigations of the lava mineralogy and whole-rock geochemistry to determine 1) the origin of the Ruby Creek lava flow with respect to Ruby Mountain and Cracker Creek, and 2) the extent of interaction between basement xenoliths and lava and tephra from Ruby Mountain.

SUMMARY

Three of the four volcanic occurrences in the Surprise Lake volcanic field were examined and found to comprise olivine-porphyritic alkaline volcanic rocks that commonly contain partly melted granitic xenoliths and quartz and feldspar xenocrysts. The largest volcanic edifice in the field, Ruby Mountain, has an estimated minimum volume of 0.59 km^3

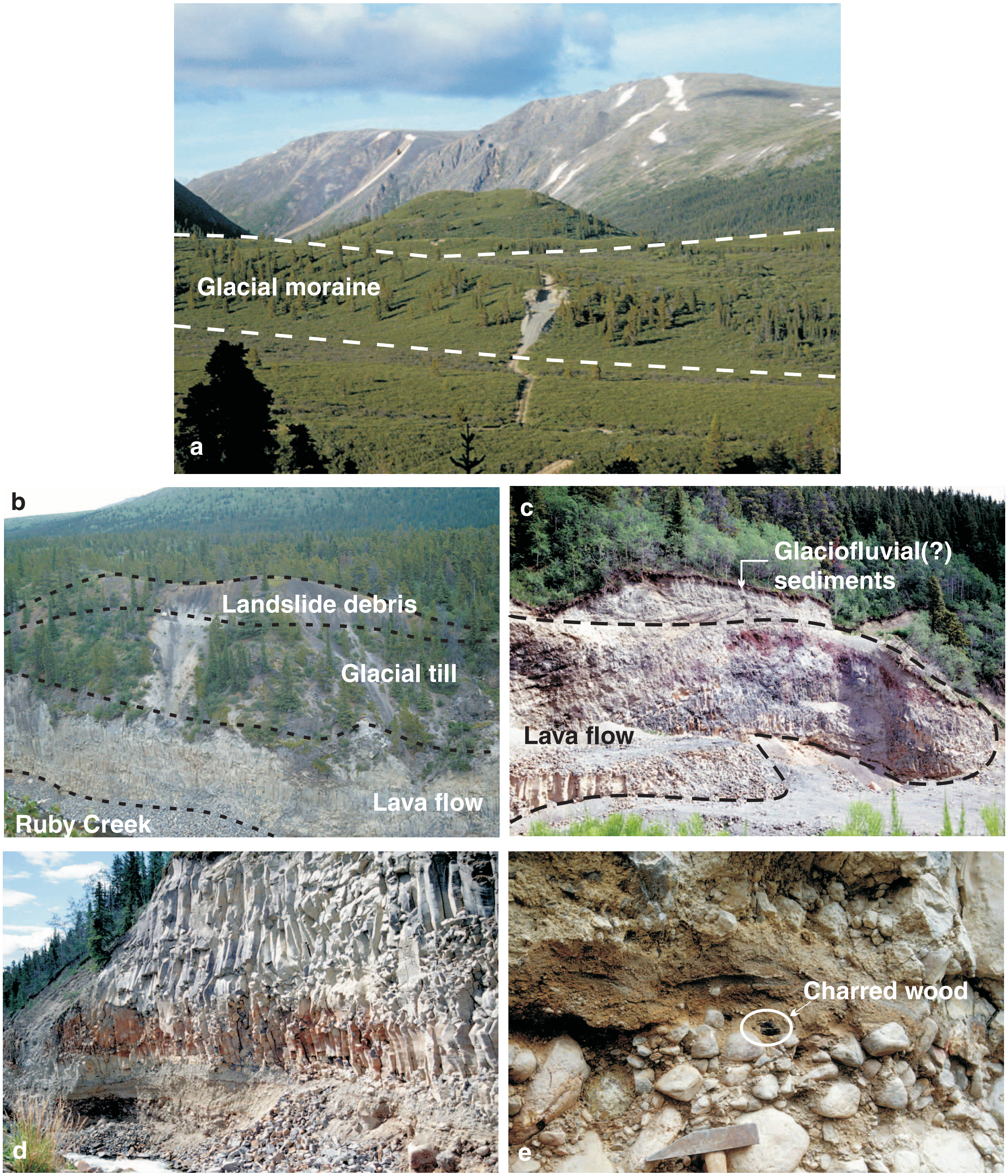

Figure 4. *Nature of various features at Cracker Creek cone and along Ruby Creek.* ***a****) View to the east of the Cracker Creek cone. The cone rises about 50 m above a lateral moraine that cuts across the middle of the view.* ***b****) View to the east to the Ruby Creek lava flow. The flow is directly overlain by glacial till, which is in turn overlain by debris from the eastern landslide. The height from Ruby Creek to the top of the landslide debris is about 60 m.* ***c****) View to the southeast of recent mining cuts into the Ruby Creek lava flow near Ruby Gold Ltd. placer operations. Bedded sediments above the lava flow appear to be glaciofluvial or deltaic. The height of the lava is about 10 m.* ***d****) View of the well jointed Ruby Creek lava flow overlying fluvial gravels with host placer gold. The height from the stream to the base of the lava flow is about 3 m.* ***e****) Close-up of rounded boulders beneath the Ruby Creek lava flow. The black material above the right end of the sledgehammer is charcoal. The hammer head is 20 cm long.*

Table 2. Major-element analyses of selected samples from Ruby Mountain (RM), Ruby Creek (RC, and Cracker Creek (CC).

Sample no.	00AB04 RC	00AB07 CC	00AB09 RM	00AB23 RM	00AB25 RM	00AB28 RM	00AB33 RM	00AB36 RM	00AB40 RM	00AB42 RM
UTM[1]	6615135N 594048E	6619135N 594639E	6619130N 593319E	6619974N 591860E	6618396N 591540E	6618604N 592099E	6619031N 591492E	6618943N 591979E	6618500N 592707E	6618500N 592707E
Elevation[2] (m a.s.l.)	973	1331	1220	1399	1903	1712	1670	1742	1410	1410
Wt. % oxides[3]										
SiO_2	47.33	47.14	47.02	47.54	47.83	48.12	47.90	46.46	48.57	47.33
TiO_2	2.23	2.09	2.31	2.17	2.14	2.15	2.15	2.37	2.12	2.22
Al_2O_3	13.89	13.56	13.82	13.94	13.82	13.86	13.79	13.82	13.76	13.83
Fe_2O_3	12.25	12.24	12.35	12.23	12.15	12.05	12.06	12.52	11.82	12.25
MnO	0.16	0.17	0.17	0.16	0.16	0.16	0.16	0.16	0.16	0.16
MgO	8.59	10.01	8.64	8.60	8.78	8.67	8.80	8.55	8.37	8.57
CaO	8.76	8.78	8.81	8.89	8.79	8.79	8.81	8.85	8.49	8.80
Na_2O	4.13	3.62	4.19	4.12	3.93	3.98	3.89	4.32	4.00	4.23
K_2O	1.63	1.36	1.61	1.53	1.51	1.56	1.56	1.90	1.76	1.71
P_2O_5	0.89	0.72	0.94	0.83	0.73	0.76	0.76	0.97	0.83	0.89
Ba[4]	623	532	682	613	590	575	581	702	621	635
Ce[4]	74	67	78	73	67	61	68	91	82	86
Cr_2O_3[4]	406	554	393	416	425	438	439	378	412	401
V[4]	186	177	188	195	178	190	185	195	179	192
Totals	99.99	100.00[5]	99.99	100.14	99.97	100.23	100.01	100.06	100.01	100.12

[1] Universal Transverse Mercator (UTM) co-ordinates and elevations are based on global positioning system measurements under NAD83
[2] m a.s.l. = metres above sea level
[3] Loss-on-ignition (LOI) values for all samples except 00AB07 (LOI = 0.18 wt. %) were below detection limits.
[4] Elements reported in parts per million
[5] Includes 0.18 wt. % LOI

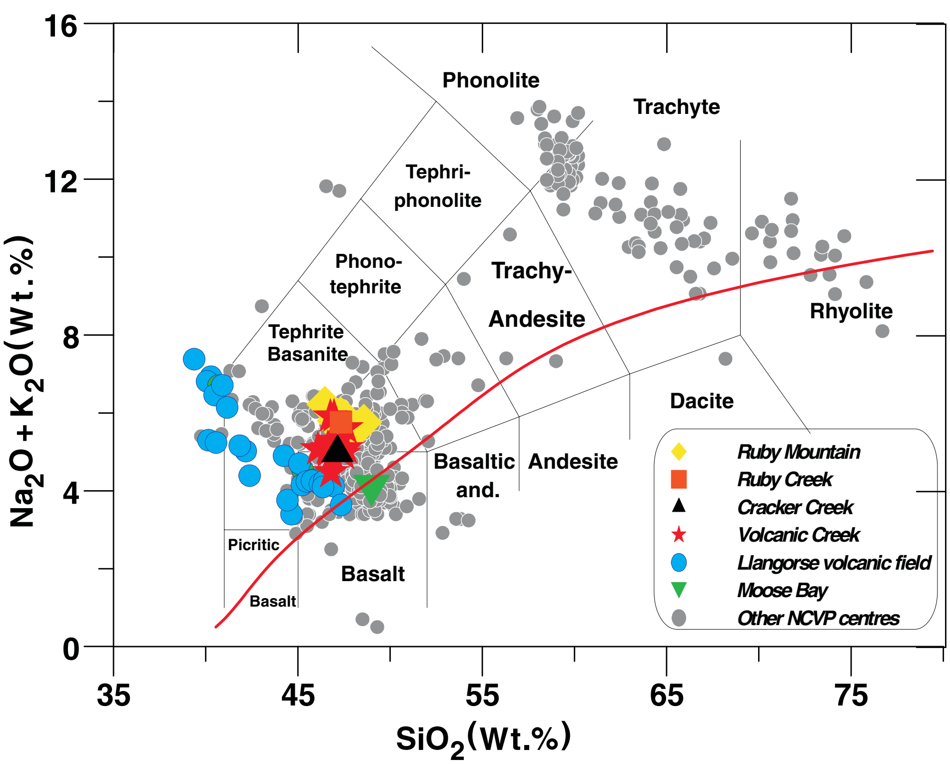

Figure 5.

Total-alkalis-versus-silica plot for samples from Ruby Mountain, Ruby Creek, and Cracker Creek. Fields are from Le Bas et al. (1986). The curved line is the alkaline-subalkaline division of Irvine and Baragar (1974). The data represented on the plot is for Ruby Mountain (Nicholls et al., 1982; this study), Ruby Creek (Nicholls et al., 1982; this study), Cracker Creek (this study), Volcanic Creek (B.R. Edwards and J.K. Russell, unpub. data, 1996; A. McCarthy and B.R. Edwards, in prep., 2002), Llangorse volcanic field (Francis and Ludden, 1995; Abraham et al., 2001; B.R. Edwards and J.K. Russell, unpub. data, 1996), Moose Bay (Erdman, 1985), other Northern Cordilleran volcanic province centres (see Edwards and Russell, 2000).

and comprises mainly scoriaceous tephra with minor lava flows. It has been modified by post-eruption glaciation and large (up to 10 per cent of the present volume) mass-wasting events. The other two volcanic features examined in the field, the Cracker Creek cone and the Ruby Creek lava flow, also show evidence of post-eruption glaciation, although the Cracker Creek cone does not appear to have been extensively modified by glacial erosion. The Ruby Creek lava flow, which is the largest lava flow in the Surprise Lake volcanic field and overlies gold-bearing placer gravels, cannot as yet be linked genetically to either the Cracker Creek vent or the Ruby Mountain vent. However, ongoing studies are aimed at differentiating between competing hypotheses for a genetic link between the lava flow and either the Cracker Creek cone or the Ruby Mountain volcano, as well as trying to document contamination of volcanic samples by granitic xenoliths and constructing a model for the physical evolution and erosional history of the Ruby Mountain volcano.

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