Usk Map Area (NTS 103I/09), Near Terrace, British Columbia: Cross-Sections and Volcanic Facies Interpretation

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INTRODUCTION

In the summer of 2005, one geologist and three geology students working for the British Columbia Geological Survey, along with three Kitselas First Nation resource technicians, surveyed the Usk map area, near Terrace, BC (Fig. 1). A major objective of the project was to identify subdivisions within the Telkwa Formation, a unit that had previously been undivided in the Terrace area. This article presents four cross-sections of the map area (Fig. 2); it is a companion article to Nelson *et al.* (2006), where a full examination of the physical features and exploration potential of the Usk map area is presented. This paper highlights the details of the newly distinguished units within the Telkwa, as well as their stratigraphic, (paleo)geographic and structural relationships to one another and to local intrusive and older Triassic and Paleozoic units. Special emphasis is placed on variations in volcanic facies that occur between and within the divisions of the Telkwa Formation. Twenty samples have been collected along these transects for whole-rock major, trace and isotope geochemical analyses. These will be incorporated into a Ph.D. thesis currently in progress by the senior author at Dalhousie University.

GEOLOGICAL SETTING

The Usk map area falls within the western portion of the Stikine Terrane, or Stikinia. Stikinia is the largest of the intermontane terranes and is composed of Paleozoic to Middle Jurassic, island-arc-related volcanic, plutonic and sedimentary rocks (Anderson, 1993). The map area also falls along the eastern boundary of the Coast Plutonic Complex, a linear belt of subduction-related plutonic rocks emplaced after the accretion of the intermontane terranes to the North American continent (van der Heyden, 1992).

The cross-sections in this paper depict three main stratigraphic units and two plutonic units. The oldest stratigraphic unit, the Zymoetz group, is correlative with Paleozoic rocks of the Stikine ‘assemblage’ in the Iskut-Stikine area (Nelson *et al.*, 2006; see also Logan *et al.*, 2000; Brown *et al.*, 1991). These units are overlain, in places, by thin, well-bedded sedimentary rocks, which are thought to be Triassic in age and are correlative with the Stuhini Group. The youngest, and by far the most voluminous, stratigraphic unit represented in these cross-sections is correlative with the Telkwa Formation, the oldest formation of the Hazelton Group (Richards and Tipper, 1976); it is composed mainly of intermediate coherent volcanic and volcaniclastic rocks. A large, multiphase, anastomosing pluton, informally named the Kleanza pluton (Gareau *et al.*, 1997a, b), is represented in these cross-sections. A second plutonic suite, belonging to the Eocene Coast Plutonic Complex, is only represented in cross-section D–D′–D″, as it outcrops mainly in the northwestern corner of the Usk map area (Carpenter Lake pluton, Fig. 2).

CROSS-SECTIONS

Detailed descriptions of the geological units that are shown in these cross-sections are presented in Nelson *et al.* (2006) and will not be repeated here; rather, this paper will focus on observations, made along the transects of the cross-sections, that may be important to the interpretation of the environment of emplacement/deposition.

Section A–A′

The A–A′ transect (Fig. 3), which crosses from Copper Mountain on the south side of the Zymoetz River to the O.K. Range on the north side of the river, highlights the features of the Paleozoic Zymoetz group, Triassic strata, and their internal structure and relationship to overlying and intrusive Jurassic units.

Apophyses of the Jurassic Kleanza pluton outcrop on Copper Mountain and in the O.K. Range. The margins of this intrusive body represent both original intrusive contacts and faulted contacts. The Kleanza pluton forms a laccolith in the northwestern and central parts of the Usk map area. The laccolith is present at a shallow depth, as depicted on the northeastern portion of this cross-section. Its geometry, in this portion of the map, is inferred from 1) its regional outcrop characteristics (for instance, plutonic rocks commonly outcrop in low lying drainages); and 2) high concentrations of dikes, up to 50% of all outcrop, with rock types similar to those of the pluton.

The Paleozoic Zymoetz group is composed of two units, a fossiliferous limestone and a volcanic unit that is composed of interbedded intermediate lapilli tuff and volcanic conglomerate and sandstone. These units are considered by Nelson *et al.* (2006) to be a subaqueous-arc edifice with limestone reefs and limy banks that were periodically inundated by volcaniclastic debris. Limestone of the Zymoetz group is coeval with the Permian Ambition For-

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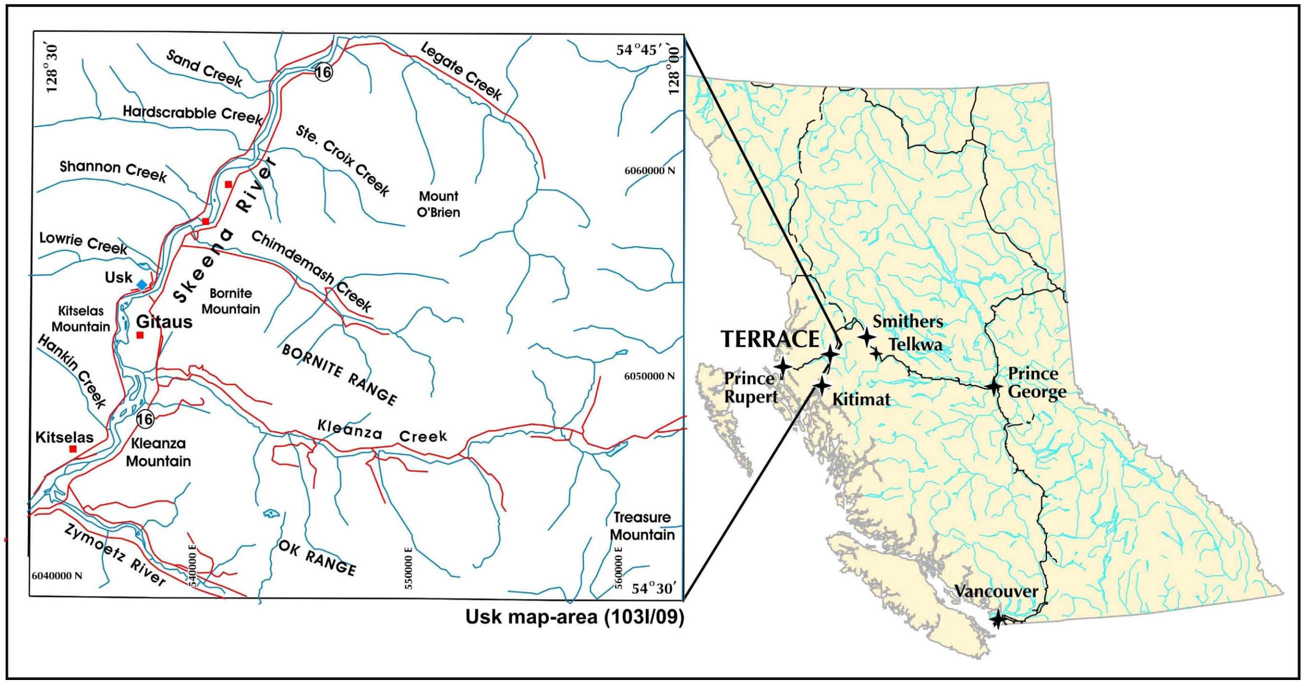

Figure 1. Location and geographic features of the Usk map area (NTS 103I/09), near Terrace, British Columbia.

mation in the Iskut-Stikine area (Gunning *et al.*, 1994); however, this limestone interfingers extensively with volcanic and volcanic-derived material, whereas the Ambition Formation postdates volcanic activity in the Iskut-Stikine area.

A thin band, less than 100 m thick, of well-bedded sedimentary rock overlies the Zymoetz group. These rocks bear a close likeness to other Triassic rocks in the Stikine Terrane. Radiolarians from this unit are currently being evaluated to confirm its age. These sedimentary rocks are composed of gray and black, pyritic radiolarian chert, in some areas interbedded with sooty black pyritic argillite. Beds are typically 5–15 cm thick and, in many outcrops, folded disharmoniously on a mesoscopic scale. These siliceous sediments represent an oxygen-starved marine depositional environment; they conspicuously lack any of the normally voluminous clinopyroxene porphyritic volcanic rocks that typify the Triassic elsewhere in the Stikine Terrane.

The Paleozoic and Triassic strata are characteristically thrust imbricated within the Usk map area. Repetitions of Paleozoic and Triassic rocks typically involve layer-parallel faults with up-to-the-south relative movement in the hangingwall. The thrust faults predate the deposition of the Jurassic Telkwa Formation and are overlain by basal conglomerate of the Telkwa Formation.

Paleozoic and Triassic strata are well exposed in the southwestern portion of the Usk map area, despite there being little evidence that this area is structurally lower than elsewhere in the map area, where they are not exposed. This leads to the interpretation that they formed a topographic high during the time of deposition of the Telkwa Formation. The presence of a proximal topographic high would explain the high-energy depositional environment of the Telkwa basal conglomerate, which is composed mainly of clasts derived from the Zymoetz group. The basal conglomerate has strong local variations in clast composition, which further supports the local presence of a Paleozoic and Triassic topographic high.

The Telkwa basal conglomerate and conglomerate of the Paleozoic volcanic unit are very similar and can easily be mistaken for one another, especially because they both contain the same types of clasts, and they may be structurally or stratigraphically in contact with one another. In general, conglomerate of the Zymoetz volcanic unit has a higher proportion of clinopyroxene porphyritic mafic rocks and quartz porphyritic dacite, and a lesser proportion of plagioclase porphyritic rocks; however, the Telkwa conglomerate can also contain these clasts where they are locally sourced from erosion of the Zymoetz group. Conglomerate of the Zymoetz volcanic unit is more commonly interbedded with volcanic sandstone with a limy matrix, and lapilli tuff. The basal Telkwa conglomerate can be uniquely identified where it contains clasts of the banded Triassic chert and sooty argillite (*e.g.*, along the northern end of this cross-section).

The basal Telkwa conglomerate is overlain by a thick unit of volcaniclastic rock composed mainly of andesitic lapilli tuff. This unit, and its relationship to the other coeval andesite unit in the map area, are described in the next cross-section.

Section B–B′

This transect (Fig. 3), which crosses from the O.K. Range on the north side of the Zymoetz River to the Bornite Range on the north side of Kleanza Creek, highlights the relationship between the two andesitic volcanic units within the Telkwa Formation, as well as other features of its internal stratigraphy.

The southwestern portion of this section shows the Zymoetz volcanic unit in faulted contact with a horst of the Kleanza pluton. Here, the pluton has been uplifted and offers a rare glimpse at its more homogeneous core, as op-

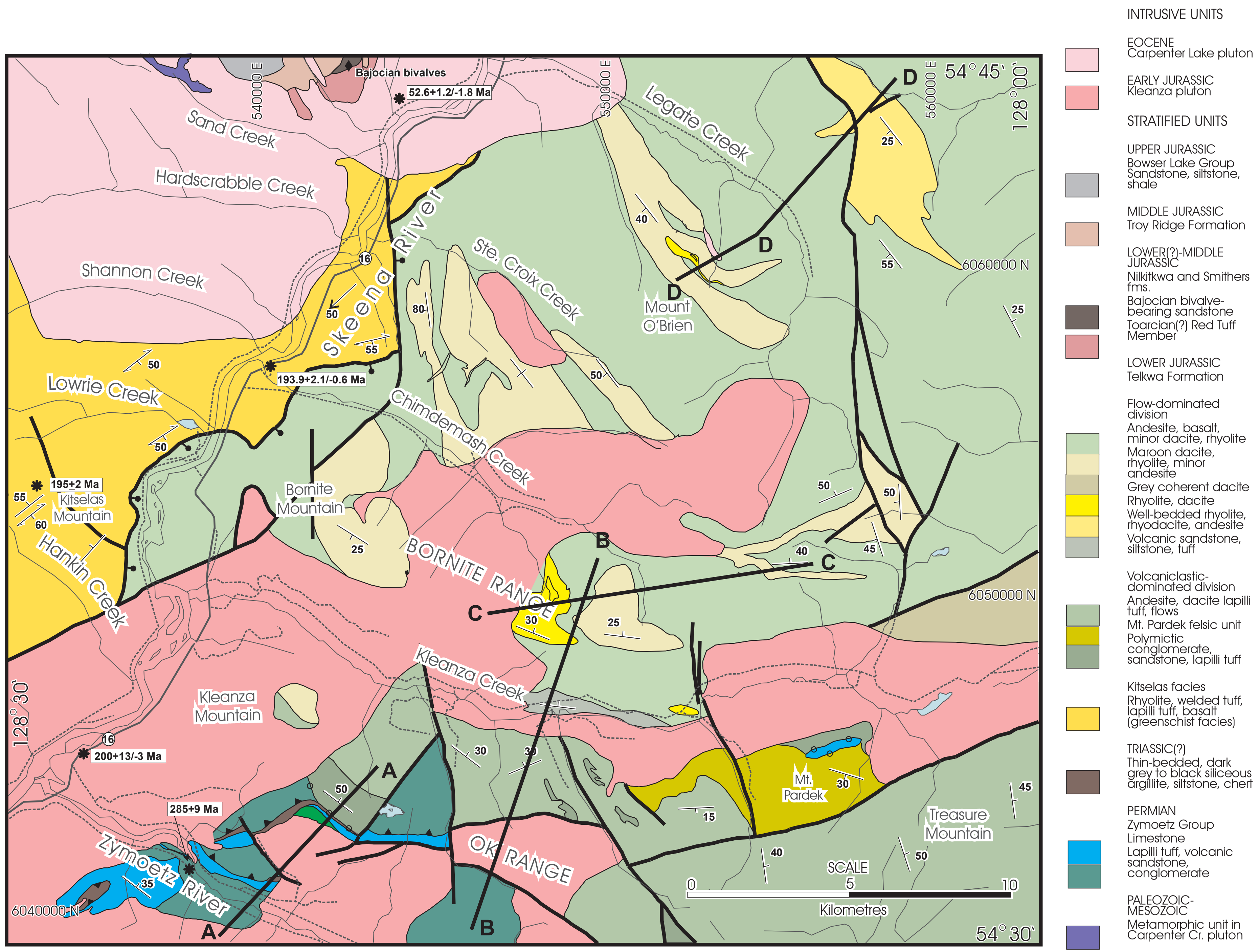

Figure 2. Generalized geology of the Usk map area, showing the location of the cross-sections

posed to the heterogeneous border phases that are normally observed. The centre of the pluton is more evolved than the border phases: it is a relatively homogeneous, coarse grained, equigranular, biotite granite with up to 60% quartz. Border phases, such as those exposed in the Kleanza Creek valley, on this cross-section are typically more mafic and are composed of hornblende±biotite granodiorite and diorite, rare granite, green microdiorite and aplite. These border phases of the Kleanza suite show extreme local variability and mutual crosscutting relationships.

Juxtaposed across the Kleanza Creek valley are distinct units of the Telkwa Formation, which Nelson *et al.* (2006) refer to as the O.K. Range – Treasure Mountain facies and Kleanza Creek facies in the south, and the Mount O'Brien facies in the north. Both are composed mainly of andesitic volcanic rocks, but the O.K. Range and Kleanza Creek facies are mainly volcaniclastic rocks, whereas those to the north are mainly coherent volcanic flow units. The differences between these units are not the result of a stratigraphic relationship; rather, they represent a paleogeographic difference in volcanic environments and depositional settings. The northern Mt. O'Brien facies is proximal to eruptive fissures and centres, and is therefore composed mainly of coherent volcanic flows. In the southern Kleanza and O.K. Range facies, there is very little coherent volcanic material; instead, they are composed mainly of primary and resedimented volcaniclastic material, particularly andesitic lapilli tuff. These are more distal facies and represent a subsiding basin. The basin accommodated large amounts of volcanic debris that erupted directly into it or washed into it from the volcanic edifice.

There are no exposures of Triassic or Paleozoic rocks, or the basal Telkwa conglomerate, beneath the andesite of the Mt. O'Brien facies. On the northern slopes of Kleanza Creek, a sequence of finely bedded green and maroon volcanic sandstone grades transitionally upward into coherent flows.

Two locally occurring bodies of dacite and rhyolite are depicted on the northeastern portion of the cross-section. Both coherent and volcaniclastic facies of these felsic rocks form irregular and discontinuous bodies within the coherent Mt. O'Brien facies andesite unit. Felsic intervals are rare in the O.K. Range and Kleanza facies, due to the distance of these rocks from the local felsic eruptive centres located to the north in the Mt. O'Brien facies. The characteristics of the Mt. O'Brien facies felsic units and their relationships with the andesitic units are discussed in further detail in the following two sections.

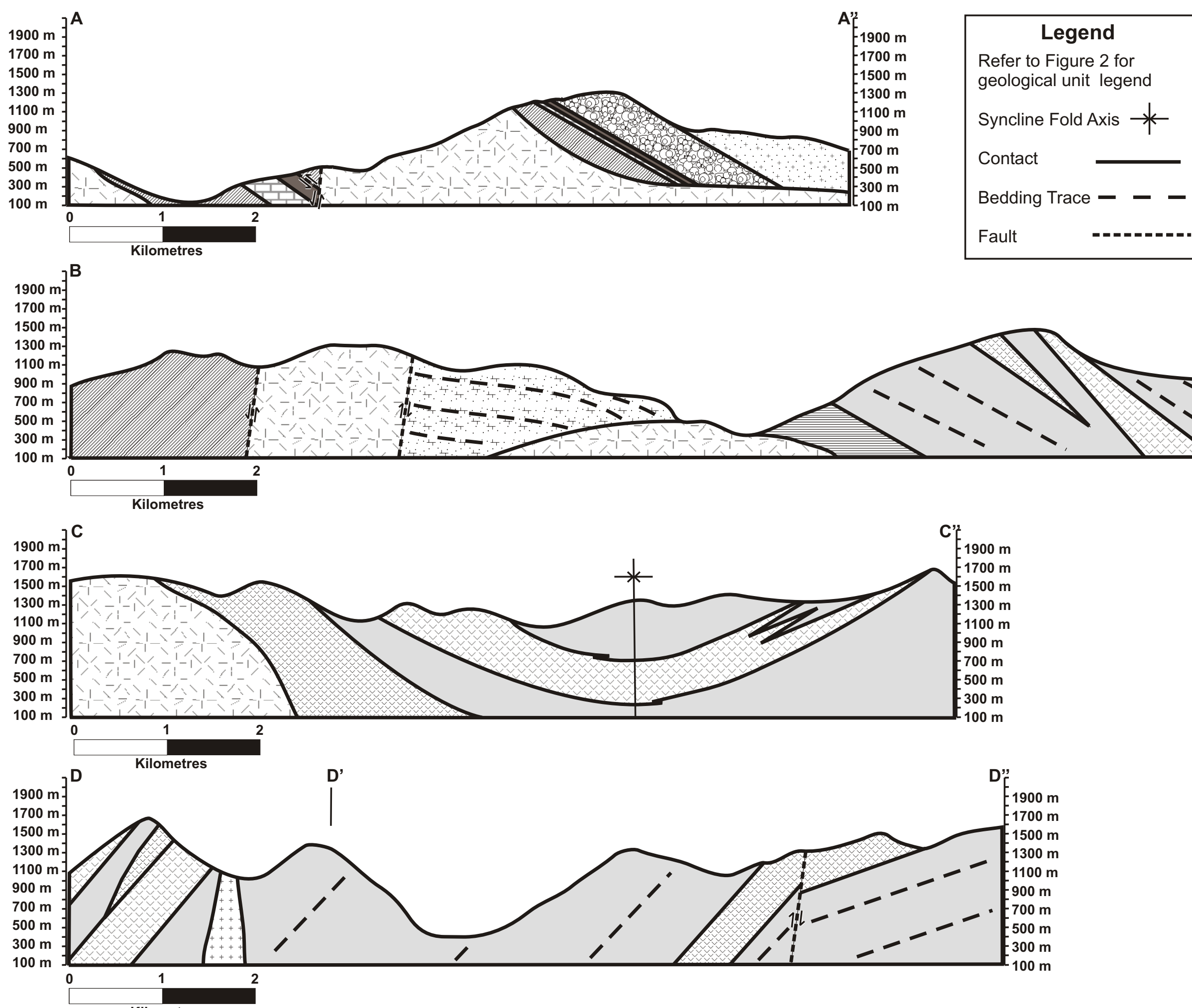

Figure 3. Cross-sections of the Usk map area. Rock unit patterns as on Figure 2.

Section C–C′

The C–C′ transect (Fig. 3), which spans a length of the Bornite Range between the headwaters of Chimdemash Creek to the north and Kleanza Creek to the south, depicts the physical distribution of dacitic and rhyolitic units within the Mt. O'Brien facies.

On the western portion of this cross-section, there is a contact between a body of the Kleanza pluton and a rhyolite volcanic unit. Closer to the centre of the intrusive body, the rock is relatively homogeneous, but, along its margin, it is composed almost entirely of dikes with variable composition, ranging from mafic to felsic. Of particular interest is the presence of highly epidotized, fine-grained, holocrystalline 'clasts'; these clasts are also found in abundance in certain tuff layers in the overlying rhyolitic units (Fig. 4). The close resemblance of many of the border phase felsic dikes to the rocks within the rhyolite unit, and the presence of holocrystalline epidotized clasts in both the pluton and the tuff layers, suggests that the contact between the pluton and the rhyolite may be transitional in the sense that the pluton was a feeder to the overlying eruptive volcanic unit.

The rhyolite unit is composed of laterally continuous layers of coherent, flow-banded white rhyolite, lapilli tuff and thin-bedded aphanitic siliceous sedimentary layers (Fig. 5). The fine-grained, well-bedded, siliceous sedimentary units may be intervals of felsic ash tuff or exhalitive chert. Lapilli tuff in this felsic unit is mono to polylithic, and some beds contain mafic as well as felsic lapilli. At least one 20 m thick bed is composed of resedimented lapilli tuff, which has scour-and-fill structures at its base and a coarsening-upward grading. Welding (*i.e.*, the flattening of pumice clasts due to compaction of hot volcanic material) is conspicuously absent in any of these beds. The continuity of beds in this unit, especially of the coherent rhyolite bodies, is unusual for these highly viscous volcanic rocks. It suggests that the section crosses very close to the volcanic centre but at a distance where beds can be deposited without being disrupted by further volcanic activity, probably on the moderately distal flanks of the eruptive edifice. The lateral continuity of beds, absence of welding, and presence of fine-grained, well-bedded sequences are all suggestive of a subaqueous depositional environment.

The dacitic unit in this cross-section is exposed on two limbs of what is interpreted to be a broad syncline. The syncline is inferred from the opposing dips of the rocks on each limb; however, within the dacitic unit, igneous layering orientations are highly variable. This can be explained by the viscous nature of the lava, the irregular topography of the underlying andesitic unit, and the general high-energy and chaotic nature of volcanic centres. The dacitic unit interfingers extensively with the surrounding andesite and typically fills paleotopographic depressions between large lobes of andesite that are typically hundreds of metres wide. In some places, thin veneers of fine-grained dacitic rock also cover paleotopographic highs. The dacitic unit is highly variable in its textures and individual facies are rarely laterally continuous. They are typically brick red or lavender in colour and variably feldspar phyric and vesicular. Coherent bodies are sometimes flow banded, spherulitic and rarely contain lithophysae (large vugs that form from the devitrification of volcanic glass). Volcaniclastic rocks include large breccia piles, lapilli tuff, and fine-bedded ash and crystal-ash tuffs. In at least two locations, lapilli tuff contains clasts of lapilli tuff (Fig. 6), an indication of multiple generations of explosive volcanism from the same centre. Other volcanic rocks are highly welded, with up to 1:10 aspect ratios on flattened pumice clasts. The overall geometry of deposition of the dacitic unit is consistent with subaerial pyroclastic flows (Wright *et al.*, 1980). The ubiquity of welded rocks in this unit also supports a subaerial depositional setting.

The andesite unit, which interfingers extensively with the dacitic unit, is composed mainly of green or maroon, vesicular, coherent flow units and minor amounts of lapilli tuff. The coherent units are fine grained to aphanitic and commonly have euhedral, lath-shaped plagioclase phenocrysts. The vesicles and amygdules, which range in size from 0.2 to 10 cm, occupy a large proportion of the coherent bodies, up to 60% by volume, and are filled with zeolite-facies metamorphic minerals, including chabazite, chlorite and natrolite (Fig. 7). These bodies form an irregular paleotopography composed of large flow units, as well as smaller flow lobes; no pillow forms were observed. The absence of pillow forms and the large vesicle size in these units is suggestive of a subaerial deposition. In addition, there is a virtual absence of interbedded sedimentary mate-

Figure 4. Holocrystalline epidotized clasts in the Kleanza pluton (left) and felsic lapilli tuff of the Telkwa Formation (right), Usk map area, near Terrace, BC.

Figure 5. Well-bedded rhyolitic ash and crystal ash tuff overlain by a 20 m thick bed of resedimented felsic lapilli tuff, Usk map area, near Terrace, BC.

rial, such as would be found in most proximal subaqueous depositional environments.

Section D–D′–D″

The D–D′–D″ transect (Fig. 3) crosses a cirque on the northern flank of Mt. O'Brien (D–D′) and then crosses Legate Creek, near its headwaters, to the northernmost mountain range in the Usk map area (D′–D″). This section crosses a small plug of probable Eocene age, and also two Telkwa rhyolitic units. It also crosses a major fault, which separates shallow-dipping strata in the north (Fig. 8) from more steeply dipping strata in the south. In addition, this section shows that regional trends in the orientation of beds are variable throughout the map area, as these beds dip to the southwest, whereas those in the other sections dip predominately to the northeast.

In the southwestern portion of this cross-section, a series of mainly coherent dacitic and rhyolitic units interfinger with andesite. These felsic units are similar to those described in cross-section C–C′. The andesite at this location also has similar characteristics to that on section C–C′; here, however, pipe vesicles may be present at the contacts between flows. Pipe vesicles commonly occur in subaerial environments where a flow passes over a moist surface, releasing vapours into the overlying lava (Wilmoth and Walker, 1993). The predominance of andesite shown in the lower slopes of the Legate Creek drainage is inferred, as this area is heavily forested and unexposed due to a thick Quaternary overburden.

The rhyolite unit in the northeastern portion of the cross-section is distinct from those elsewhere in the Usk map area. It is composed of a wide variety of coherent and volcaniclastic, 1–40 m thick beds of lapilli, ash and crystal-ash tuffs, and coherent rhyolite flows and domes that are transitional into flow breccias. This unit is also composed of approximately 30% dacite and 20% andesite beds. In one location, white flow-banded rhyolite was extruded through

Figure 6. Lapilli tuff with a 'clast' of a previously formed lapilli tuff, Usk map area, near Terrace, BC.

Figure 7. Amygdaloidal andesite, the vesicles partly filled with pink chabazite, Usk map area, near Terrace, BC.

Figure 8. Shallow-dipping, well-bedded layers in the northernmost rhyolitic unit (cross-section D'–D''), Usk map area, near Terrace, BC.

what was a nonlithified, red dacitic, crystal-ash tuff, creating an interval of peperitic white rhyolite in a red dacitic groundmass (Fig. 9). The andesite unit in this portion of the cross-section is composed of volcaniclastic and coherent flow rocks that are also bedded on a 1–40 m scale. Both the felsic and mafic rocks in this portion of the map area have been affected by high-angle, synvolcanic faults, which show between 1 and 10 m of vertical displacement. Rare welding of pumice clasts in rhyolitic beds suggests a subaerial depositional environment; however, limestone is found in the interstices of some andesite breccia, which suggests subaqueous deposition. In addition, rhythmic layering and normal grading of some tuff beds are also suggestive of subaqueous deposition by density currents. The volcanic rocks in this portion of the map area may have been deposited on a partly emergent, partly submerged volcanic edifice.

GEOLOGICAL HISTORY AND PALEOGEOGRAPHY OF THE STUDY AREA

The oldest rocks represented in the Usk map area belong to the Paleozoic Zymoetz group, which consists of limestone and volcanic rocks that were deposited on the limy shelf of an arc edifice. It was overlain by well-bedded Triassic chert and argillite in an oxygen-starved marine environment. These units were thrust imbricated prior to deposition of the Jurassic Telkwa Formation. During the Jurassic, they are interpreted to have formed an upstanding topographic high, which was present in the southwestern portion of the map area. These rocks were eroded and, along with a Telkwa volcanic influence, formed a basal Telkwa conglomerate, also exposed mainly in the southern portion of the map area. Overlying the basal conglomerate is a thick unit of mainly andesitic primary and resedimented lapilli tufts. These are interpreted to have been deposited in a mainly subaqueous, subsiding basin. Coeval, coherent volcanic rocks, which are voluminous to the north of Kleanza Creek, are the proximal and effusive equivalents of volcaniclastic rock deposited in the south. The northern section comprises andesite, dacite and rhyolite eruptive units, which interfinger extensively. Evidence of both subaerial and subaqueous deposition are present, often in close geographic or stratigraphic proximity to one another, suggesting that these rocks were deposited on a partly emergent arc edifice. Units of all ages have been intruded by the Jurassic Kleanza pluton and smaller bodies of Eocene age that relate to the eastern margin of the Coast Plutonic Complex. The relationship between the Kleanza pluton and the overlying Telkwa volcanic rocks is, in part, transitional, and similarities between the border phases of the pluton and Telkwa volcanic units suggest that these plutons were direct sources of volcanic magmas.

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Figure 9. Peperitic, flow-banded white rhyolite in a red dacitic tuff groundmass, Usk map area, near Terrace, BC.

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