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to Fiona Katay
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October 26th 2015

Dear Fiona Katay,

Having spent > 40 years wandering around different parts of the Rockies I had never come across extensive copper mineralization in Paleozoic carbonate rocks. Maybe there are other showings, and I'm just not aware of them, but if you have time this "note" maybe of "metallogenic" interest ?!

Many thanks for help, through my daughter Cathryn Lennox, in Fernie, in guiding me to some very helpful information in "mapPlace.ca" I was unable to locate myself.

Kind regards

Roger Wallis

A rare (?) occurrence of COPPER mineralization in Cambrian age, carbonate rocks within the Main Ranges of the Rocky Mountains, Vertebrae Ridge, British Columbia, NTS 82N/13

Roger Wallis, Ph. D., P. Eng (On).
October, 2015

A rare (?) occurrence of COPPER mineralization in Cambrian age, carbonate rocks within the Main Ranges of the Rocky Mountains, Vertebrae Ridge, British Columbia, NTS 82N/13

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SUMMARY

Recent deglaciation has exposed two zones of extensive, structurally controlled, copper mineralization, with outcropping strike lengths of ±2km and ±200m in the vicinity of Vertebrae Ridge in the Main Ranges of the Rocky Mountains of British Columbia.

Both zones occur in structures which cut Lower/Middle Cambrian limestones, dolomites and dolomitic shales.

There are very few (any?) other occurrences of copper mineralization known to be hosted by Paleozoic carbonate strata in the Rockies so this locality maybe of some metallogenic interest.

INTRODUCTION

(1) Discovery History

In August 2014, on a mountaineering trip to Vertebrae Ridge I flew by helicopter from Bush Harbour, Kinbasket Lake, see Location map. Our preferred campsite had no water so instead we chose our second campsite option. Totally by chance (serendipity) we landed on a large malachite stained outcrop - the No. 1 Copper Zone! Subsequent exploration delineated a ±2km strike length.

In August 2015, on a follow-up visit to the area, there was much less snow cover than in 2014, and the No. 2 Copper Zone was found whilst crossing talus on two separate climbing trips and a ±200m strike length was delineated.

These notes are simply the consolidation of observations made whilst on the mountaineering trips. No systematic mapping, sampling or note taking was undertaken.

Wheeler's (1963a) geological map shows that these zones of copper mineralization were completely covered by glaciation when GSC regional mapping was completed prior to 1962. However, recent deglaciation has exposed two zones of structurally constrained copper mineralization, see Figures 1 and 2 and numerous photographs.

(2) **Metallogenic Implications**

Though lead-zinc (Pb-Zn) mines and mineralization, hosted by Palaeozoic carbonates, are well known throughout the Main Ranges of the Rocky Mountains the occurrence of COPPER (Cu) mineralization within these rocks appears to be exceeding rare (?).

Economic concentrations of chalcopyrite, in solutions with moderate saline concentrations is very limited below threshold temperatures of ±350°C. The average continental geothermal gradient is ±30°C/km, so, in the absence of some specific localized zones of high heat flow (e.g. Volcanics, Igneous intrusions) chalcopyrite bearing solutions are unlikely to be generated above depths of 10-12km.

However, the Rocky Mountain Paleozoic carbonate sequences, at the western margin of the miogeosynclinal basin, lying above the Paleoproterozoic crystalline basement, only have a thickness of ±6-8km (see Figure 4.2, p.121, Monger and Price, 2000). So, though this sedimentary thickness permits the generation of inter-basinal fluids with temperatures of >100°C, sufficient to transport sphalerite/galena - lead/zinc fluids, it is insufficient to generate the 350°C fluids required to transport copper bearing fluids.

Thus, the discovery of TWO extensive zones of structurally constrained copper mineralization that crosscut, and thus post-date, folded, thrusted and faulted limestones, dolostones and calcareous shales of Middle and Upper Cambrian age, that lie east of the Chatter Creek fault, i.e. within the Main Ranges of the Rocky Mountains is unexpected, and these are very rare occurrences?

(3) Regional Geological Setting based on Wheeler, 1963 a/b

The author has used Wheeler's (1963 a,b) map and rock descriptions throughout this note rather than the much more recent British Columbia Energy and Mines 1:1 million scale geological map and structural data plotted on Google Earth images.

Wheeler's geology is plotted directly on the Federal 1:250,000 topographic map 82N, hence it is possible to relate his rock distribution and structures directly to peaks, rives and glaciers. However, the BC 1:1M geological compilation only provides a few isolated mountains for geographic control. Thus for this part of 82 N/13 only Solitude/Stovepipe Mtns. are provided as fixed reference points.

There are numerous contrasts/conflicts between Wheeler's geology and that of the B.C. 1:1M map and the Google structures, for details/discussion see Section (4).

On Wheeler's map (1963a), and in his report (1963b), the Chatter Creek fault is one of the major regional structural elements of the western Rocky Mountains.

The Chatter Creek fault lies immediately west of Vertebrae Ridge (Fig. 1). The Chatter Creek fault dips steeply to the west and it juxtaposes older rocks on the west against younger rocks on the east, i.e. it is a thrust fault.

3.1 Stratigraphy (see Table 1 for more complete details)

In the Vertebrae Ridge area the older rocks lying to the west of the Chatter Creek fault are Wheeler's Unit 3. This consists of a lower unit of shales/slates/phyllites and an upper unit of quartzites (the Solitude Range of mountains). At the top of the succession limestone units contain Lower Cambrian trilobites.

East of the Chatter Creek fault and forming the line of major summits of the Vertebrae Ridge are Wheeler's Unit 13. This consists of two formations: the lower is a of cliff forming limestones; the upper unit is more recessive and contains Middle Cambrian trilobites.

The host rocks of the two copper zones is Unit 14. Again there are two units: a lower, ±300m, thick grey limestone which contains a recessive orange, brown dolomitic shale; and an upper unit, ±150m, consisting of two grey coloured, cliff forming limestones separated by an orange coloured, more recessive dolomite. This unit is of Middle Cambrian age. Copper Zone #2 lies entirely within Unit 14, whereas Copper Zone #1 is within Unit 14 but at the contact with Wheeler's Units 16 and 17.

Unit 16 is a variably coloured, unit of orange slate and intercalated beds of grey limestone and is Upper Cambrian in age.

Unit 17 is a major cliff forming, grey limestone of Upper Cambrian age.

3.2 Intrusive Rocks

Just west of Stovepipe Mtn. at the head of Chatter Creek are two "bodies" of dark green weathering syenite composed of K feldspar and chlorite.

Outcrops of the lower member of Unit 3 near to the intrusive bodies are characteristically pink and carry much potash feldspar, plagioclase and amethystine quartz.

These bodies cut Unit 3, Lower Cambrian rocks, but otherwise are of unknown age. They are 2 and 3km respectively SW of the Copper Zones.

Other bodies of syenite are known in the general area, see Figure 4, and Section 3.4 below.

3.3 Structure

From Wheeler (1963b) "The Rocky Mountains in the triangular block lying east of the Chatter Creek fault to Prattle Creek (Figure 1) is a complexly and tightly folded and faulted synclinorium, trending NW and overturned to the NE. The west limb is essentially vertical (this is the line of the Vertebrae Ridge peaks - and consists of highly asymmetric folds with long vertical and short horizontal limbs and fold axes dipping at 45° to the SW). Subsidiary folds SE of the

Sullivan River are upright (see photos) but those along strike to the SE are overturned to the NE and have axial planes dipping 45° SW (see photos). Besides the numerous thrust faults the central part of the synclinorium is cut by several west dipping normal faults. The faults trend more northerly than the axes of the folds, hence the faults cut the folds, see Figures 1, 2, 3 and 8.

3.4 Known Showings (Figure 4)

B.C.'s MinDep files for 82N/13 indicate there are NO known Base Metal, let alone copper, showings anywhere in the area.

There are only FOUR showings listed in the MinDep Files for this area (see Figure 4):

(1) MinFile 67010 Nepheline syenite, at Sullivan River. Geog. Ref. 082N080

(2) MinFIle 67011 Nepheline syenite, at Caribou Creek, Solitude Mountain, Geog. Ref. 082N081

(3) MinFile 83037 Travertine, Columbia 1 showing. Geog. Ref. 082N095

(4) MinFile 83037 Travertine, Alpine 1 showing. Geog. Ref. 082N094

The two nepheline syenite bodies (1)/(2) above were mapped by Fyles (1960) and are described (in Wheeler, 1963b) as "broad, dyke-like bodies of alkaline syenites were mapped near the mouth of Sullivan River and on upper Caribou Creek. Plagioclase, microcline-microperthite, feldspathoids, hornblende, and biotite characterize the former; and microcline; nepheline, biotite, minor carbonate, amphibole the latter. These bodies cut Lower and Middle Cambrian rocks".

(4) Some comments of the differences between the B.C. 1:1M geological structures and Wheeler's 1963 a/b map and reports

There are some very significant differences between the two data sets:

- In stratigraphy
- In rocktype distribution
- In location of faults

4.1 Stratigraphy (Figure 5 and Table 1)

Both Wheeler and the 1:1M map divide the region into a SW area of clastics and a NE area of carbonates.

SW area of Clastics.

Wheeler's SW area of clastics has just ONE unit, his Unit 3 divided into Upper and Lower divisions. However, the 1:1M map divides Wheeler's Unit 3 into FIVE subunits each with specific distribution on the ground, see Figure 5. But the distribution makes no sense when related to Wheeler's structure on his map/cross-section and the topography.

One's question is: "Where did the information to subdivide and show the distribution of these five units come from?".

Has there been any systematic, on the ground, geological mapping of 82 N/13 since Wheeler?

There is no easily accessible reference to such mapping in the B.C. E and M files. It would be interesting to know how such delineation was accomplished - is there, in fact, a data source I have failed to locate?

NE area Carbonates

Wheeler has 4 Units: his 13/14/16/17

The 1:1M map has 5 Units: 6/7/8/9/10

See Figure 6 and Table 1

On the basis of geographic distribution rather than by rocktype:

Wheeler's 17 is equivalent to 1:1M 10

Wheeler's 16 is equivalent to 1:1M 9

The correlation of Wheeler's 13/14 to the 1:1M 6/7/8 simply makes no sense!

The 1:1M units 7 and 8 are both described as CLASTIC sediments, this simply is NOT so in the Vertebrae Ridge area - where >90% of rocks are Carbonates.

So the same question arises as with the SW area of clastics, where did this revised stratigraphy and rock distribution come from? Has there been new detailed, on the ground mapping since Wheeler? If so how does one access this data?

4.2 Rocktype distribution

Referred to above but the 1:1M map fails to indicate the presence of the syenite intrusions at the head of Chatter Creek.

4.3 Structure (Figure 6)

(i) Folds: Wheeler's map shows the distribution of all major fold axial traces. The Google satellite presentation shows NO folds axes.

(ii) Faults: Wheeler shows fault traces but has NO symbols on the map to indicate they are Normal or Thrust Faults. The 1:1M map does indicate whether they are Normal or Thrust.

(iii) Location of faults: The BC Google Earth location of Faults numbers 2-8 is more or less a fair representation of Wheeler's mapped faults. However, the Chatter Creek Thrust Fault has 2 completely different locations on the two maps, different by 2km! See Figure 6. For Wheeler, the Chatter Creek Fault juxtaposes older clastics against younger carbonates; but on the Google Earth presentation the Chatter Creek Fault lies within the clastics sequence, with NO fault at the clastic/carbonate boundary. This is a radically different interpretation, and the reason for this change comes from where?

(5) THE COPPER ZONES - Descriptions

No. 1 Zone

As shown by Wheeler (1963a) this area was completely glaciated whilst geological mapping was completed prior to 1962 so it is no surprise that the mineralized outcrops were not reported. Recent deglaciation has exposed outcropping copper mineralization along a strike length of ±2km, with a width of 50-100m, the mineralization is very steep west dipping to vertical. There are excellent 3D outcrops along and across the strike.

As shown by Wheeler (1963a) the main host structure of the No. 1 Zone is a major, steeply west dipping, Normal Fault, which juxtaposes younger rocks (Unit 17) to the west against older (Unit 14) rocks to the east, see Figs. 1-2, 7-8.

Subsequently the earlier Normal fault has been reactivated by significant strike slip shearing to form a major shear zone. Movement is predominantly dextral, with some sinistral indications, and is mainly confined to the margins of the earlier normal fault.

The host rocks of the shear zone are the asymmetrically folded grey, black, orange and yellow coloured limestones and dolomites and orange dolomitic shales of Unit 14. To the west no contacts with Unit 17, massive grey limestone, were located being hidden under talus/scree, lakes or ice.

At the top of the Gully (Fig. 7) excellent exposures (see photographs) demonstrate the cross cutting nature of the fault/shear zone while trending 330° and abruptly truncates Unit 14 rocks striking at 300°.

Later, this major shear zone has been reactivated, episodically, by numerous periods of extension, both within and beyond the sheared margins, (see photographs). This extension is accompanied by the emplacement of multigenerational systems of quartz veins, stockworks and breccia complexes with accompanying pyrite-chalcopyrite-bornite mineralization in the core of the shear zone, and non-sulfide bearing calcite/dolomite vein systems on the margins.

The multigenerational quartz vein systems cross cut each other and, generally, they cross cut earlier, vivid orange/red limonitic calcite dolomite-(siderite) vein systems. However, a later system of calcite-dolomite veins cross cut the quartz vein systems. This late generation of calcite-dolomite veins extends laterally well beyond the margins of the shear system.

Only the quartz vein/breccia systems carry sulphides: pyrite-chalcopyrite-(bornite) and their carbonate alteration products: malachite and azurite.

There is a definite asymmetry to the shear systems. The hanging wall (west side) is dominated by a wide (10-30m) zone of extremely vivid ochre coloured, limonite (+ siderite?) strained orange dolomites/dolomitic shales (see photographs) which have been extremely sheared. This zone has many crosscutting, polyphase calcite/dolomite vein systems but no obvious quartz veins and there is no malachite staining.

In contrast the footwall (east side) is much less shearing and no vivid ochre colouration. The rocks in contact with the shear zone are broken and brecciated rather than sheared. Quartz veins extend almost to the footwall contact and malachite staining and copper sulphides occur within 2-5m of the contact, see photographs and Fig. 8.

No. 2 Zone

Has an observed strike extent of ±200m and is best exposed where it occurs in a vertical cliff lying north and east of "Peak #16". This locality lies near the axis of the syncline shown by Wheeler, Fig. 2. Here the syncline is overturned to the east and lies quite near the trace of Wheeler's more westerly fault. The cliff face displays a steeply overturned fold cut by a steeply dipping fault/shear zone system which is hosted by Unit 14, grey limestones and brown grey dolostones. Quartz vein debris occurring as blocks, talus and scree carries abundant malachite and pyrite/chalcopyrite. The "in situ" vein system in the cliff face above the talus/scree was not visited.

(6) THE COPPER ZONES - Comments

(i) The No. 1 Zone does lie along one of a very few major Normal faults in the area. The normal fault became the focus for a later developing shear zone. The shear zone later became a zone of extension, which permitted the introduction of silica/sulphides. So being the site of a "long life" fault system did this allow for the introduction of copper bearing fluids from considerable depth?

One cannot develop the same "long life" scenario for No. 2 Zone, but that maybe why it is a smaller system?

(ii) The mineralization is POST-all folding and faulting of the host rocks; interesting so is the emplacement of the two syenite bodies west of Stovepipe Mtn and the intrusions and mineralization line up along a SW/NE trend, but surely this is just coincidence? The syenite bodies are small and are 2-3km distant, it seems very improbable that they could be an external, mid-late Palaeozoic heat source to generate the copper mineralization.

(iii) There are NO known other volcanic/igneous intrusions in the vicinity to act as either or both the heat source and be the origin of the mineralization.

(iv) The triptych of "source-transport-deposition" this is an 'enigma'!

Source: There is no obvious source for Cu minerals in the carbonate rocks. At depth there are only relatively clean clastics (no thick sequences of black shales) which sit on quartzofeldspathic crystalline Hudsonian Proterozoic basement rocks, neither make an obvious source.

Transport: As pointed out in the Introduction there is insufficiently thick sedimentary succession to reach the 350°C temperatures to permit chalcopyrite solubility and there are no known external heat sources - e.g. volcanic/igneous intrusions.

Deposition: Is fine! Cooling temperatures and/or interaction with meteoric water.

(7) CONCLUSION

The question of academic/metallogenic interest, despite the low grade/low tonnage potential of these two zones, is "How rare or common is copper mineralization in Middle/Upper Cambrian Carbonate rocks of the Rocky Mountains?"

(8) RECOMMENDATION

Zone #1 is so well exposed and so accessible that the area would make a great B. Sc. thesis mapping and metallogenic project, providing someone can pay for the 7 minute helicopter flight from Bush Harbour.

(9) ACKNOWLEDGEMENTS

- To my companions in 2014: Mark Henderson and Mark McDermott,
- and my companions in 2015: Norm Greene and Bill McKenzie,

- and to Fiona Katay, P. Geo. Regional Geologist, Kootenay Boundary District, for her helpful assistance in locating data in B.C.'s MapPlace website.

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Click on "Search BCGS Publications" – then search by "NTS Map"

For Mineral showings (MINFILE):

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TABLE 1

Wheeler (1963 a/b) Geological Units 82N/13

Youngest to Oldest

Upper Cambrian

Unit 17

Upper Formation: Two cliff forming grey, molted and laminated limestones separated by brownish grey recessive dolomite. Crinoids and algal masses.

Middle Formation: Recessive, interbedded grey limestone, brown , grey and green slate, limestone conglomerate, oolite and algal limestone.

Lowest Formation: Cliff forming, well bedded, brownish grey weathering wavy laminated limestone, mottled grey and pale brown limestone, dolomite and chert lenses.

Unit 16

Characteristically a varicoloured recessive formation, brown, orange, green, grey slate, numerous interbeds of oolitic limestone and limestone conglomerate. In part correlates with Walcott's (1928) Sullivan Formation (see Table 2 below).

Middle Cambrian

Unit 14

East of the Bush River divisible into two Formations, but west of Prattle Creek (i.e. the Vertebrae Ridge area) the lower formation contains more limestone making it difficult to separate from the upper formation.

Upper Formation: Has two cliffs forming limestone units separated by more recessive dolomite and limestone. The cliff forming limestones are variably light and dark mottled varieties locally featuring ribbon banding and in some places oolitic beds and intraformational limestone breccia. Algal buns, up to 6 feet across, occur in the uppermost limestone bed.

Lower Formation: Recessive, principally brown and subordinate greenish weathering, thin bedded slate-like dolomite, maroon and green slates, grey limestone and limestone breccia. This formation is correlative, in part, with the Arctomys Formation of Walcott (1928), see Table below.

Unit 13

Upper Formation: Contains argillaceous beds and consequently is rather more recessive. Limestones form bedded units upto 50 feet thick, with 1-5 inch beds with uneven, prickly weathered surface. Locally the limestone is oolitic and broken, with cross-bedding and worm burrows.

Lower Formation: Very resistant, major cliff forming limestone, up to 2000ft thick. In detail it is thin bedded but from afar it shows little structure. Dark grey to light grey limestone partly altered to brown weathering dolomite. This unit is probably equivalent to the Eldon Formation.

Cambrian

Unit 3

Upper Unit: Consists of more than 2000ft thickness of interbedded quartzite, slate and minor limestone and forms great cliffs on Solitude Mtn. and neighbouring peaks, White quartzite, 200ft. thick, forms the basal bed of the Upper Unit. It is succeeded by alternating units, each about 200ft. thick, of resistant grey, greenish, brown miceous quartzite and slate with some conspicuous maroon beds. Two limy beds, each 40-50 feet thick, occur 900-1500ft. above the base and contain numerous trilobite fragments of Lower Cambrian age.

Lower Unit: Consists of thin bedded, greasy, dark grey and olive green slates, with which are associated gritty beds with feldspar and quartz. The base of this unit has not been recognized.

NOTE: The uppermost unit is exactly the same rock sequence seen in the Hamill Formation and the lower unit is exactly the same as the Horsethief Creek Formation rocktypes as seen in the Selkirks. Wheeler does not make this comparison, but if one goes from one location to the other within a space of a few days, they seem identical!

TABLE 2

B.C. 1:1M Geological Map

District Geology 82N/13

Geological Units

Youngest to Oldest

Unit 10 muCmMBL 530-510Ma
Middle to Upper Cambrian
Mistaya, Bison Creek, Lyell Formations
Limestone and calcareous sediments

Unit 9 muCmS 530-510Ma
Middle to Upper Cambrian
Sullivan Formation
Mudstone, siltstone, shale

Unit 8 muCma 536-510Ma
Middle to Upper Cambrian
Arctomys, Waterfowl Formations
Coarse clastic sediments and red beds

Unit 7 muCmSMW 536-510Ma
Middle to Upper Cambrian
Stephen and Mt. Wilson Formations
Shale, mudstone and siltstone

Unit 6 muCmCT 536-510Ma
Middle to Upper Cambrian
Cathedral, Tanglefoot, Elko, Gordon Formations
Limestone, dolomitic shale

Unit 5 CMGma 570-536Ma
Lower Cambrian

Gog Group; Mahto Formation

Quartzite

Unit 4 uPrCmGM 1000-536Ma

Upper Proterozoic to Palaeozoic Formations

Gog Group: Mural, McNaughton, Jasper Formations

Undivided sediments, limestone to sandstone

Unit 3 uPrCmGJ 1000-536Ma

Proterozoic to Palaeozoic Formations

Gog Group: Jasper Formation

Quartzite

Unit 2 uPrMiu 1000-570Ma

Upper Proterozoic

Miette Group: Upper Division, Byng Formation

Unit 1 uPrMiu 1000-570Ma

Proterozoic

Miette Group: Middle Division, Old Fort Point Formation

Coarse clastics

(11) LIST OF FIGURES

(12) LIST OF PHOTOGRAPHS

Photographs 1 to 45, see detailed descriptions.

Photographs

Photographs of the No. 1 Copper Zone

(A) Unit 14 Rocktypes/Fold Styles

(1) Tight folding in Unit 14 grey limestones/orange dolomites along strike to the NW from the No. 1 Cu Zone, as seen on the south side of the ridge SE of the Sullivan River. The folds have upright to slightly SW inclined axial planes

(2) Same as (1) but, at the viewer's left hand end of the ridge (west end), one can see the stratigraphic contact with Unit 13, massive grey limestones.

(3) Steeply east dipping, grey limestones and orange dolomites of Unit 14, immediately east of the No. 1 Cu Zone. This is typical of the asymmetric folding occurring to the SE of photos (1)/(2) above, with long steep limbs and short horizontal limbs, dipping east, fold axes plunge to the SW.

(4) Asymmetric anticlinal hinge zones in Unit 14 limestones/dolomites immediately east of No. 1 Cu Zone.

(5) In the foreground are gently plunging anticlinal hinge zones in Unit 14 limestones and dolomites; the tents lie on the crosscutting No. 1 Cu Zone, which is the rusty zone in the middle ground. In the background, forming the hill, are the massive, unfolded, grey limestones of Unit 17.

(6) Layered limestones/dolomites of Unit 14 to the SE of No. 1 Cu Zone, showing overturned asymmetric folding, long steep limbs, short horizontal limbs, axial planes dip to the SW.

(B) <u>Extensions of No. 1 Cu Zones to NW/SE</u>

(7) The NW extension is lost under scree/talus downslope from the orange col on the ridge in the middle ground, and extends down to the very lowest large snow patch.

(8) The No. 1 Cu Zone lies under the large central gully. On the left (west) the lower orange dolomites and dolomitic shales are Unit 16. Above them forming the ridge crest are grey limestones of Unit 17. This is Peak 4, Pt. 2,510m (Figures 2/3). To the right (east) of the gully are orange dolomites and grey limestones of Unit 14 (on the ridge leading to Peak 5, Pt. 2,470m). The gully marks the trace of an early west dipping Normal fault, down throwing Units 16/17 to be juxtaposed against Unit 14.

(9) From the base of the Gully looking SE, the No. 1 Cu Zone is lost under the glacier in the immediate foreground.

(C) <u>Contacts of the No. 1 Cu Zone with its Host Rocks.</u>

(10) Above the gully, looking NW to Peak 4, Pt. 2,510m, see Figures 2/3. In the foreground WNW striking vivid orange dolomites and black limestones of Unit 14 dip steeply east, asymmetric folds are seen on the right side of the photo. At the gully the 300° striking rocks are abruptly truncated by the 330° striking shear zone marked by the prominent white quartz veins. Beyond the gully on Peak 4 lie east dipping Unit 17 limestones.

(11) Close up of Photo 10. For scale are two people (in white/red) in lower right foreground. Note: there are no outcrops of the contact of the shear zone/No. 1 Cu Zone with Unit 17 rocks, the contact is always covered by scree/talus, lakes or glacial ice.

(12) Above the Gully looking SE to Peaks 5/6, Pt. 2,470m/2,480m (see Figures 2/3), which consist of steeply east dipping orange dolomite and dark grey limestones of Unit 14. The shearzone and No. 1 Cu Zone cuts across the foreground. The two large boulders are of Unit 17 grey limestone.

(13) East Contact of the Shear Zone. In the foreground are flat lying, asymmetric folded dolomites of Unit 14, see anticlinal fold nose on the right edge of photo. In middle ground are dark, silicified/limonitic rocks (the No. 1 Cu Zone) which abruptly cross cut and truncate the folded Unit 14 rocks. The tents are pitched on the Cu Zone.

(14) East contact of the Shear Zone. Folded dolomites/limestones of Unit 14 are strongly brecciated and broken at the contact of the shear zone/No. 1 Cu Zone.

(15) East contact of the shear zone, as (14), folded Unit 14 dolomites/limestones are brecciated and broken at the contact of the shear zone.

(16) East contact of the Shear Zone lies along the snow patch on the upper left of the photo. Note: brecciation/shearing but also extensive quartz veining, silicification and malachite, limonite, chalcopyrite (middle ground, left side of the photo).

(17) West contact of Shear Zone. In conspicuous contrast to the east contact there is little to no quartz veining and no copper mineralization but instead there is a ±20m wide zone of pervasive strike slip shearing (with predominantly dextral movement and SE plunging lineations). It has extreme ochre colouration from iron staining - limonite (rare siderite) of the orange dolomite units. Multigenerational dolomite/calcite veins both cut and are deformed by the shearing. No actual contact against Unit 17 grey limestone was located.

(18) West contact zone. Within the zone polyphase shearing produces disrupted shear lozenges. In this area it is not easy to discern “real” dip, strike slip movement directions or lineation azimuth/plunge. Note: Extreme ochre colour.

(19) West contact zone. Extreme ochre colour of limonite stained, thinly layered orange dolomites, with superimposed folds/foliation, shearing, brecciation and white carbonate veins (dominantly calcite) both subparallel to and crosscutting bedding and folds.

(D) Surface expression of No. 1 Copper Zone

(20) Looking SE across “Central Lake” (Fig. 3). In the foreground are typical dark rust zones (limonite and sulphides) and massive and anastomosing quartz and carbonate veins beyond the lake. On the left are orange dolomites of Unit 14; in the centre the No. 1 Copper Zone; on the right grey limestone talus of Unit 17.

(21) Looking SE along “North Lake” (fig. 3). In the foreground and just beyond the tents is the abrupt, steeply west dipping, contact between Unit 14 grey limestones and orange dolomites on the left and the dark limonite/sulphide/quartz veined rocks of the No. 1 Cu Zone on the right.

(22) A similar view to photo (21), with the mineralized zone lying between the lake and the tents, and pale coloured dolomite slabs lying beyond the tents. in the distance are the strongly overturned folds of Unit 14.

(E) Structures within the No. 1 Copper Zone

(23) Highly silicified rock and quartz vein ribs with very strong limonite staining form the central part of the No. 1 Cu Zone.

(24) Strongly sheared dolomite in the foreground has a very sharp east contact with the silicified, quartz veined, limonite stained rocks of the No. 1 Cu Zone, abundant malachite at the waterfall with notable pyrite/chalcopyrite in the fresh broken rock.

(25) Multigenerational stock work quartz veining in the center of the zone, host rock is orange dolomite.

(26) Multigenerational quartz stockwork veining, most sulphides are associated with the crosscutting (across the photo from left to right) generations of quartz veins, rather than the earlier generation quartz veins which run from top to bottom of the photo.

(27) Later quartz stockwork veins cut earlier highly silicified breccia.

(28) Heavily limonite development on quartz stockwork cutting earlier silicified breccia, replacing dolomite, seen in upper left corner.

(29) End state of dolomite replacement, completely silicified rock cut by quartz vein stockworks.

(30) As (29).

(31) Extensional, vertical quartz vein, well to the east of the east contact of the No. 1 Cu Zone, with later dextral shear zones (dip SE) which systematically displaces the quartz vein. The vein cuts grey limestones.

(32) Extensional, vertical quartz vein cuts orange dolomites, again well to the east of the east contact of the No. 1 Cu Zone.

(F) Mineralization

(33) The central core of No. 1 Cu Zone. All rocks are silicified and very strongly "limonitized". There is a complex mass of polyphase quartz veining and quartz breccia's, with "islands" of Unit 14 sheared, layered dolomite. Almost everywhere within the conspicuous limonite (after pyrite) are zones/patches/joint covered zones of malachite (and more rarely azurite). On broken faces (not easy to do without sledge hammer on silicified rock) pyrite chalcopyrite-bornite-marcasite are extremely fine grained but even so are very conspicuous.

(34) - (40) Views of malachite along the ±2km strike length of the No. 1 Cu Zone.

Photographs of the No. 2 Copper Zone

NB: Unfortunately NOT comprehensive, in 2014 the Zone was snow covered, and in 2015 the writer had lent his camera for the day!

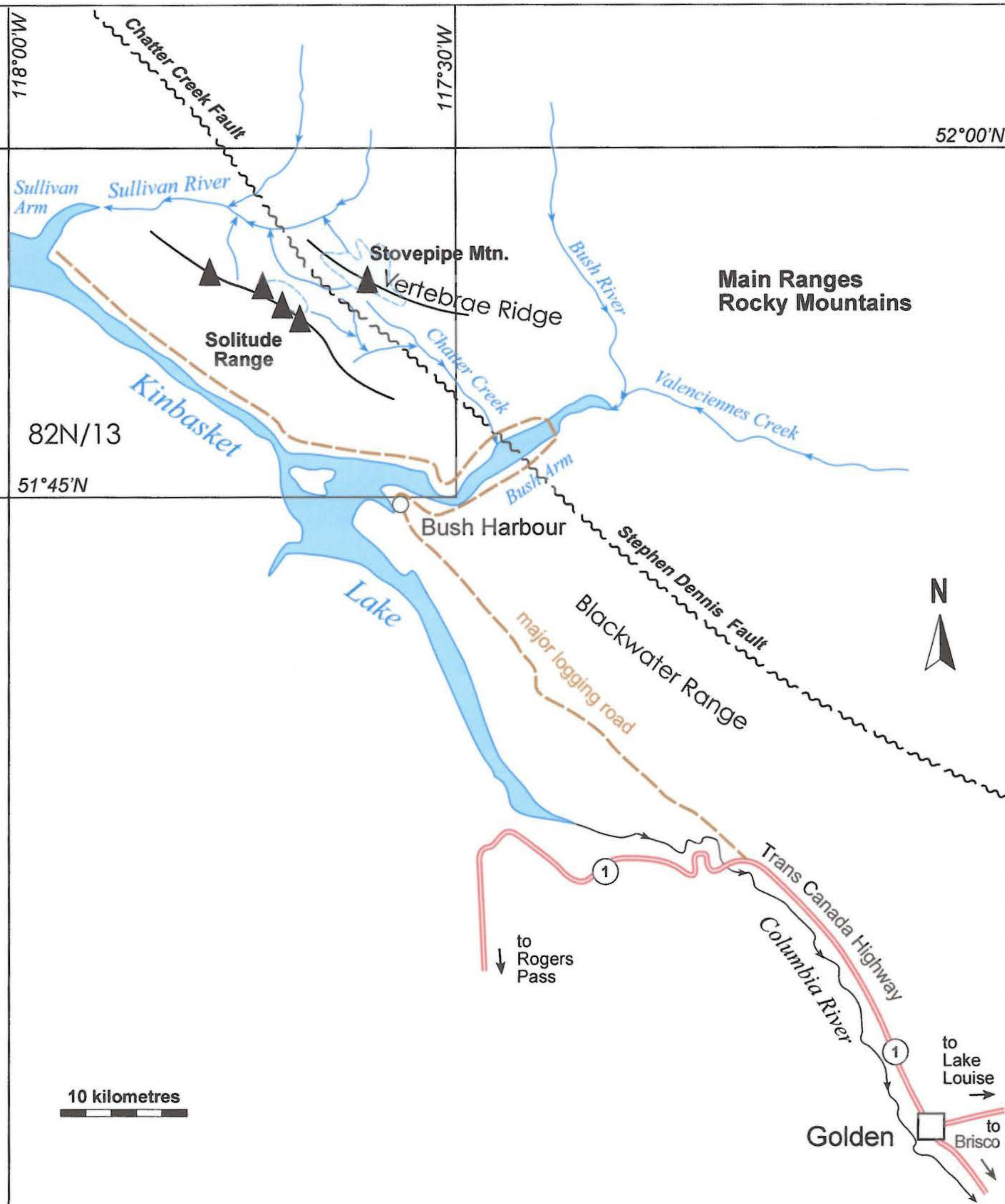
(2.1) Zone in 2014. On the skyline from the left to right are peaks 17/18/19 (see Figure 2). The flat topped rock area to the right of the ice fall on the left edge of the photo is peak 16. No. 2 Cu Zone extends from ice glacier on the left edge below the large black cliff under the snow patch with the prominent circular ice patch and through a gap in the central orange dolomite cliff band and then is hidden below the extensive glacier on the right side of the photo.

(2.2) 2014 photo. As photo (2.1) but can clearly see the typical colours of the layered Unit 14 rocks, the cliff of black limestone behind and orange dolomite in front, Also the typical extreme asymmetric fold style of long vertical and short horizontal limbs and axial planes dipping to the SW.

(2.3) 2015 photo. This asymmetric fold style is very well seen in this photo on the east face of Peak 15, on the left behind glacier. The upper part of the mountain dips 10° W; the summit ridge behind dips 80° E; the front face below the summit ice cap dips 80° E. To the right of the steep glacier, No. 2 Cu Zone extends below the black cliff across a wide ice patch and through the cliff band on the right of the photo.

(2.4) 2015 photo. Typical crush zone in the axial core of one the asymmetric folds near No. 2 Cu Zone, but NOT at the exact Cu Zone outcrop, typical well layered Unit 14 dark limestones. The triangular snow summit in the distance is Stovepipe Mtn., Peak 22, Unit 13 grey limestone forms the grey peak, 21 on its left and the robust ridge on its right.

(2.5) 2015 photo. Standing on the trace of the No. 2 Cu Zone with orange dolomites in the foreground, the zone is lost under the glacier in the middle/ far distance.



Vertebrae Ridge

Rocky Mountains

British Columbia

Location and Access

RHW, October 2015

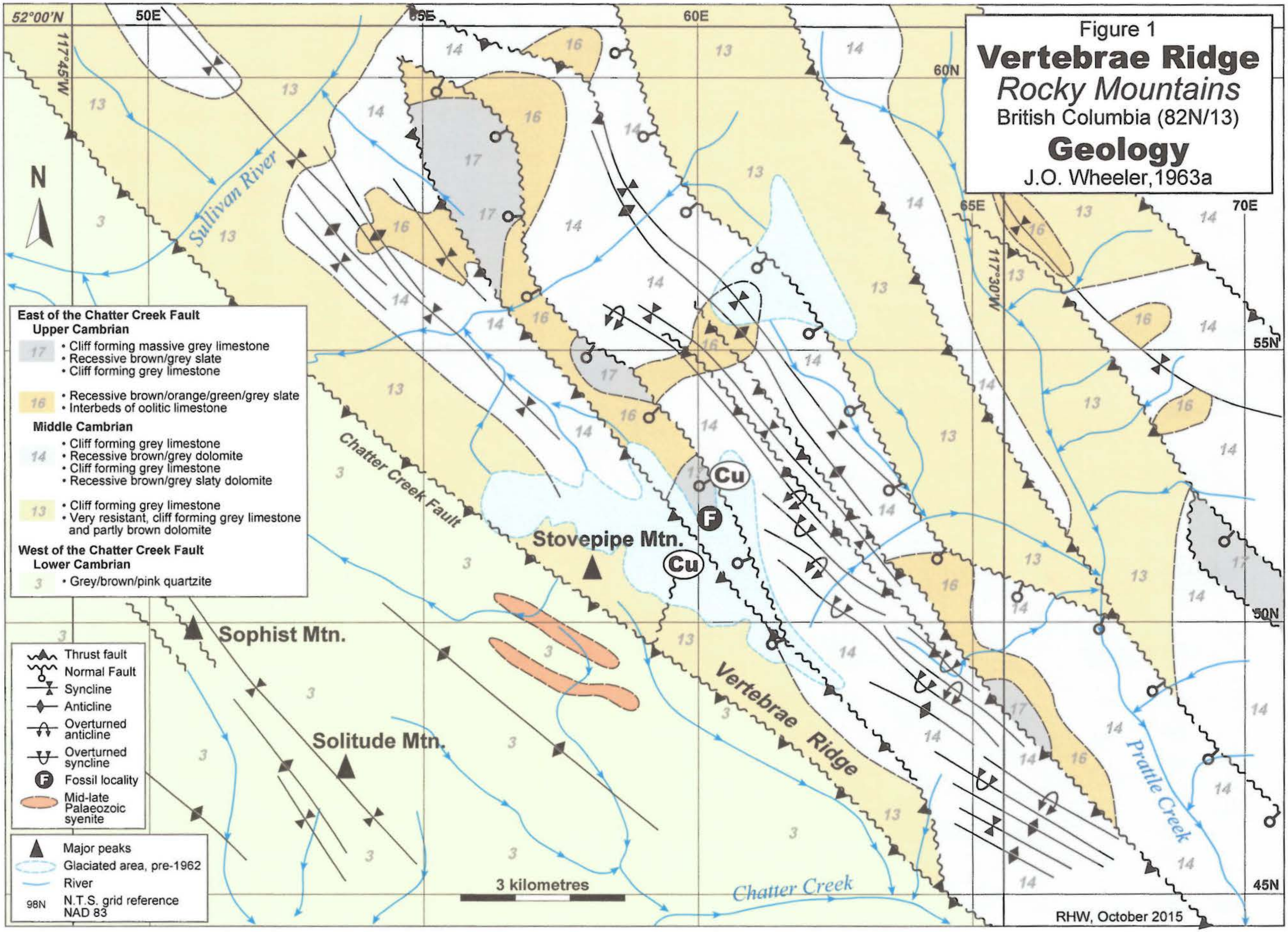


Figure 1
Vertebrae Ridge
Rocky Mountains
British Columbia (82N/13)
Geology
J.O. Wheeler, 1963a
52°00'N
117°45'W
117°30'W
50E
55E
60E
65E
70E
60N
55N
50N
45N
N
Sullivan River
Chatter Creek Fault
Stovepipe Mtn.
Sophist Mtn.
Solitude Mtn.
Vertebrae Ridge
Chatter Creek
Prattle Creek
Cu
F
East of the Chatter Creek Fault
Upper Cambrian
17 • Cliff forming massive grey limestone • Recessive brown/grey slate • Cliff forming grey limestone
16 • Recessive brown/orange/green/grey slate • Interbeds of oolitic limestone
Middle Cambrian
14 • Cliff forming grey limestone • Recessive brown/grey dolomite • Cliff forming grey limestone • Recessive brown/grey slaty dolomite
13 • Cliff forming grey limestone • Very resistant, cliff forming grey limestone and partly brown dolomite
West of the Chatter Creek Fault
Lower Cambrian
3 • Grey/brown/pink quartzite
Thrust fault
Normal Fault
Syncline
Anticline
Overturned anticline
Overturned syncline
Fossil locality
Mid-late Palaeozoic syenite
Major peaks
Glaciated area, pre-1962
River
98N N.T.S. grid reference NAD 83
3 kilometres
RHW, October 2015

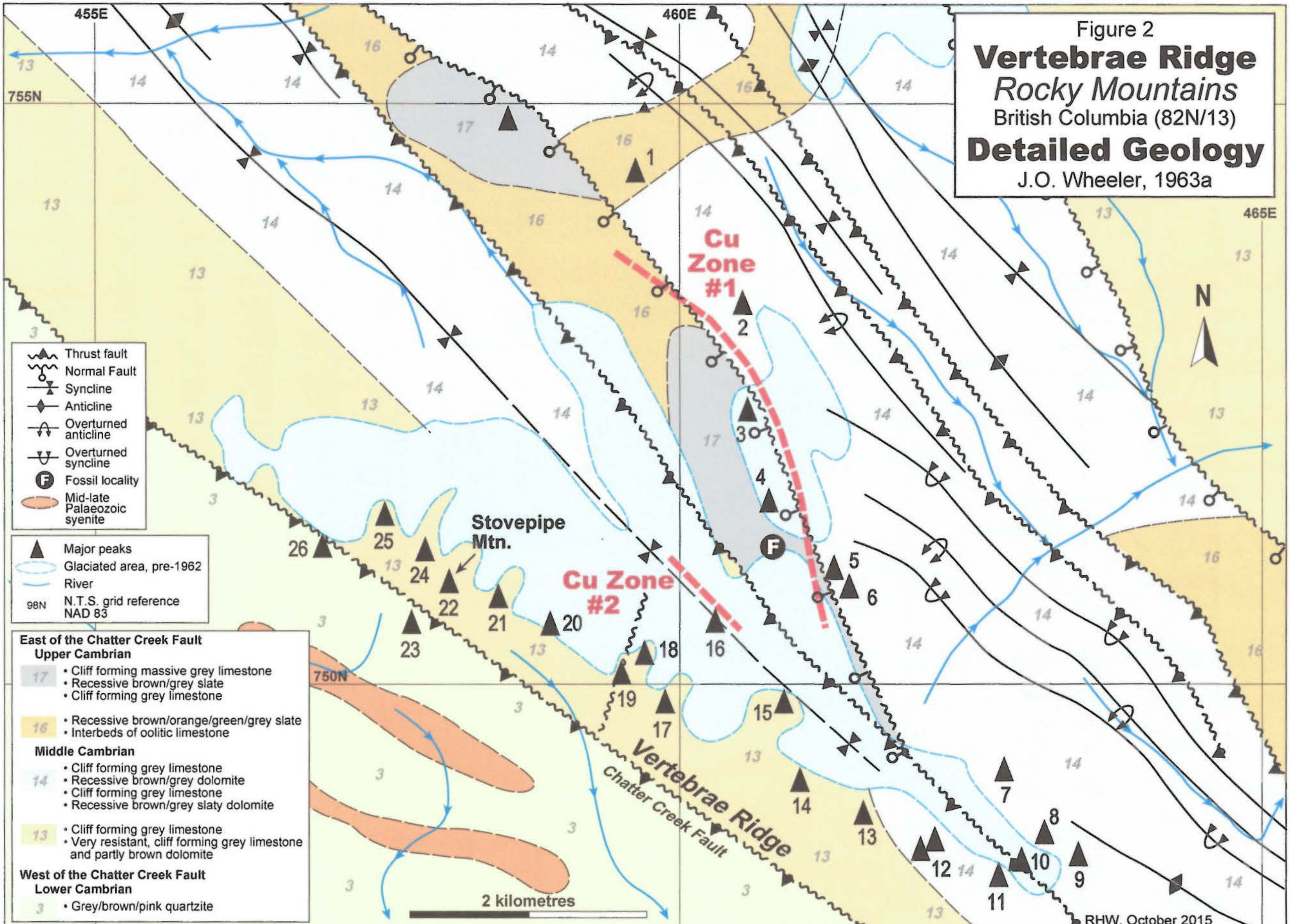
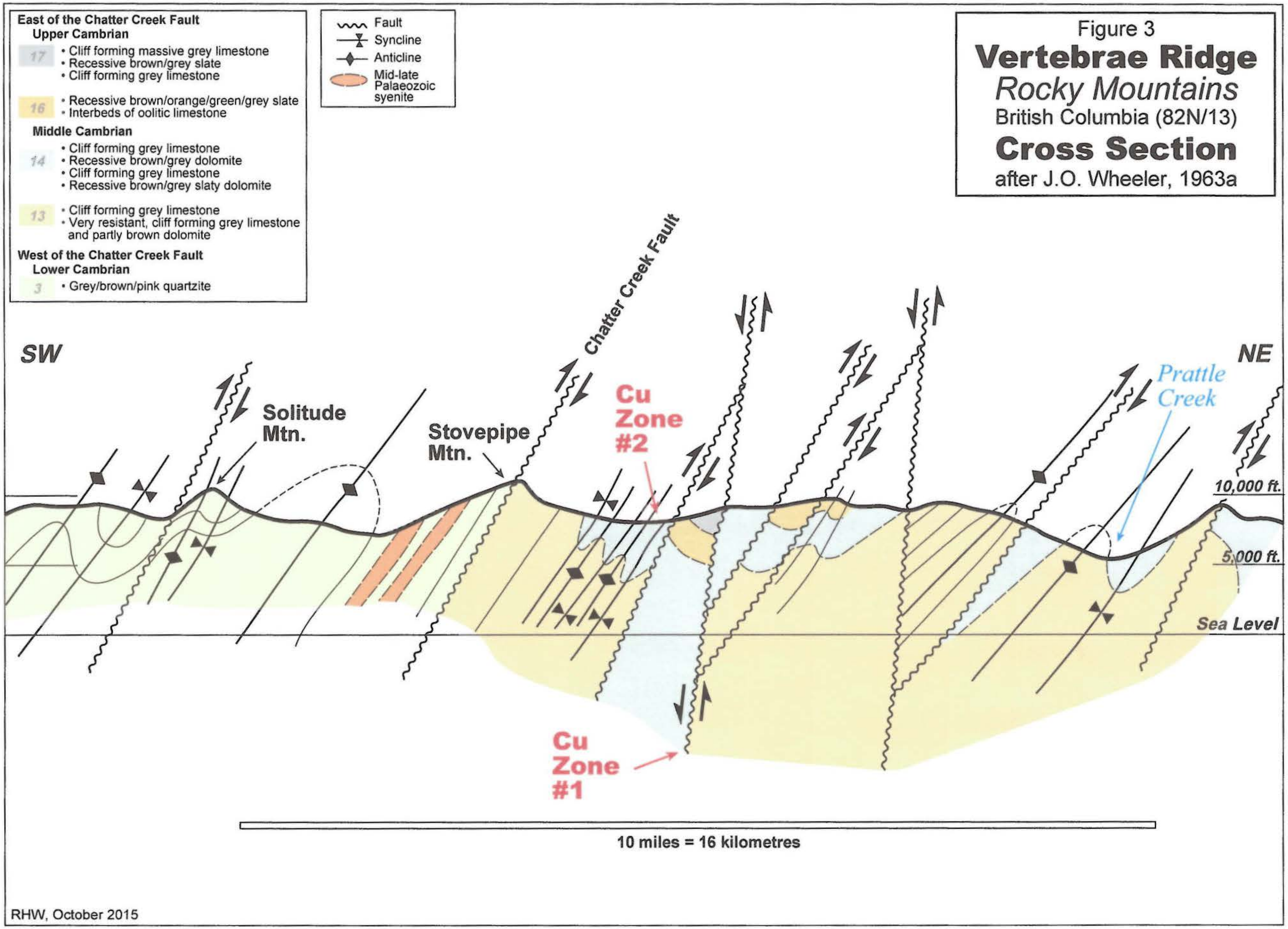


Figure 2
Vertebrae Ridge
Rocky Mountains
British Columbia (82N/13)
Detailed Geology
J.O. Wheeler, 1963a
455E
460E
465E
755N
750N
N
Cu Zone #1
Cu Zone #2
Stovepipe Mtn.
Vertebrae Ridge
Chatter Creek Fault
Thrust fault
Normal Fault
Syncline
Anticline
Overturned anticline
Overturned syncline
Fossil locality
Mid-late Palaeozoic syenite
Major peaks
Glaciated area, pre-1962
River
98N N.T.S. grid reference NAD 83
East of the Chatter Creek Fault
Upper Cambrian
17 • Cliff forming massive grey limestone • Recessive brown/grey slate • Cliff forming grey limestone
16 • Recessive brown/orange/green/grey slate • Interbeds of oolitic limestone
Middle Cambrian
14 • Cliff forming grey limestone • Recessive brown/grey dolomite • Cliff forming grey limestone • Recessive brown/grey slaty dolomite
13 • Cliff forming grey limestone • Very resistant, cliff forming grey limestone and partly brown dolomite
West of the Chatter Creek Fault
Lower Cambrian
3 • Grey/brown/pink quartzite
2 kilometres
RHW, October 2015



RHW, October 2015

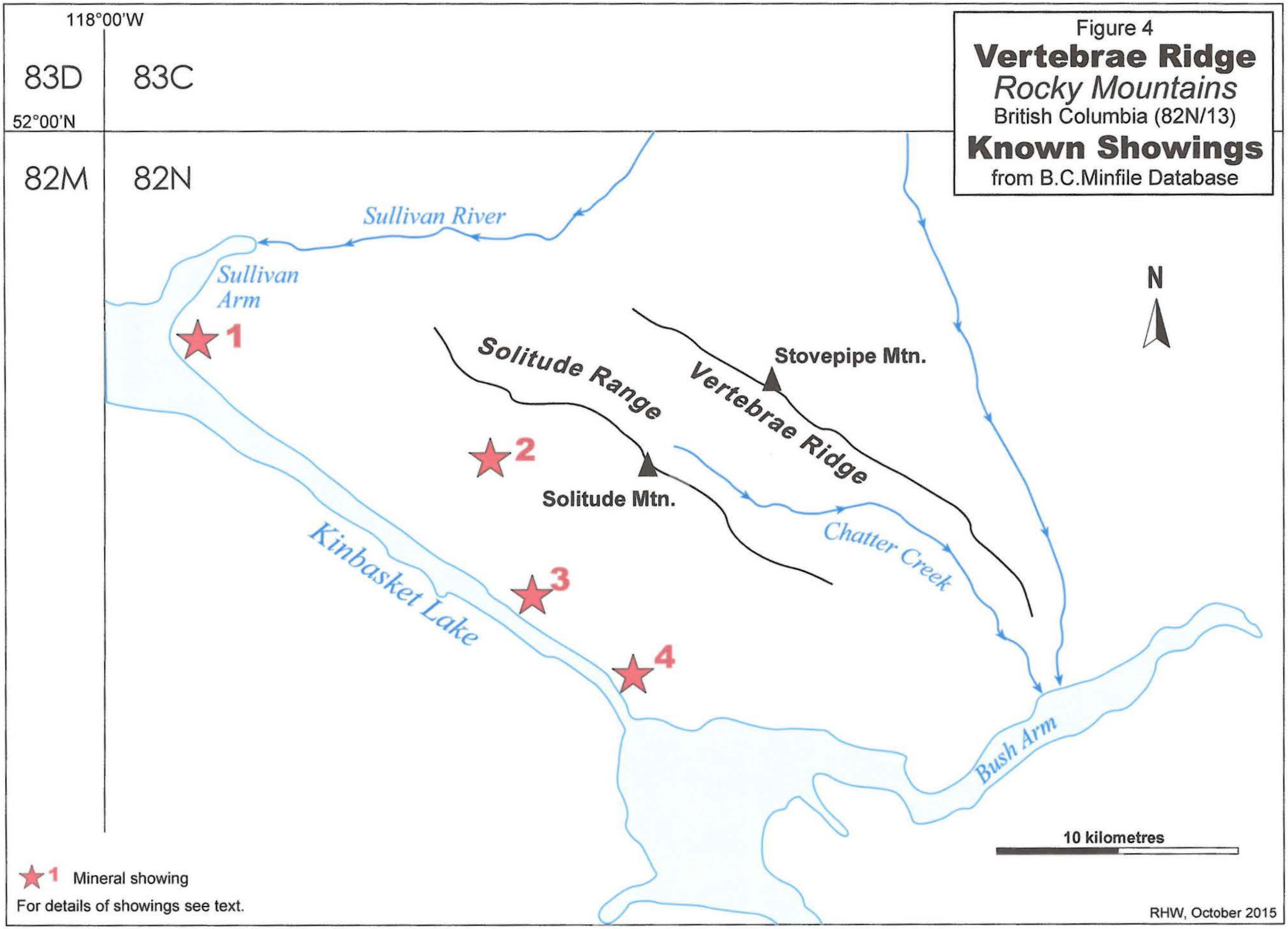


Figure 4
Vertebrae Ridge
Rocky Mountains
British Columbia (82N/13)
Known Showings
from B.C.Minfile Database
118°00'W
52°00'N
83D
83C
82M
82N
Sullivan River
Sullivan Arm
Solitude Range
Vertebrae Ridge
Stovepipe Mtn.
Solitude Mtn.
Chatter Creek
Kinbasket Lake
Bush Arm
N
1
2
3
4
10 kilometres
Mineral showing
For details of showings see text.
RHW, October 2015

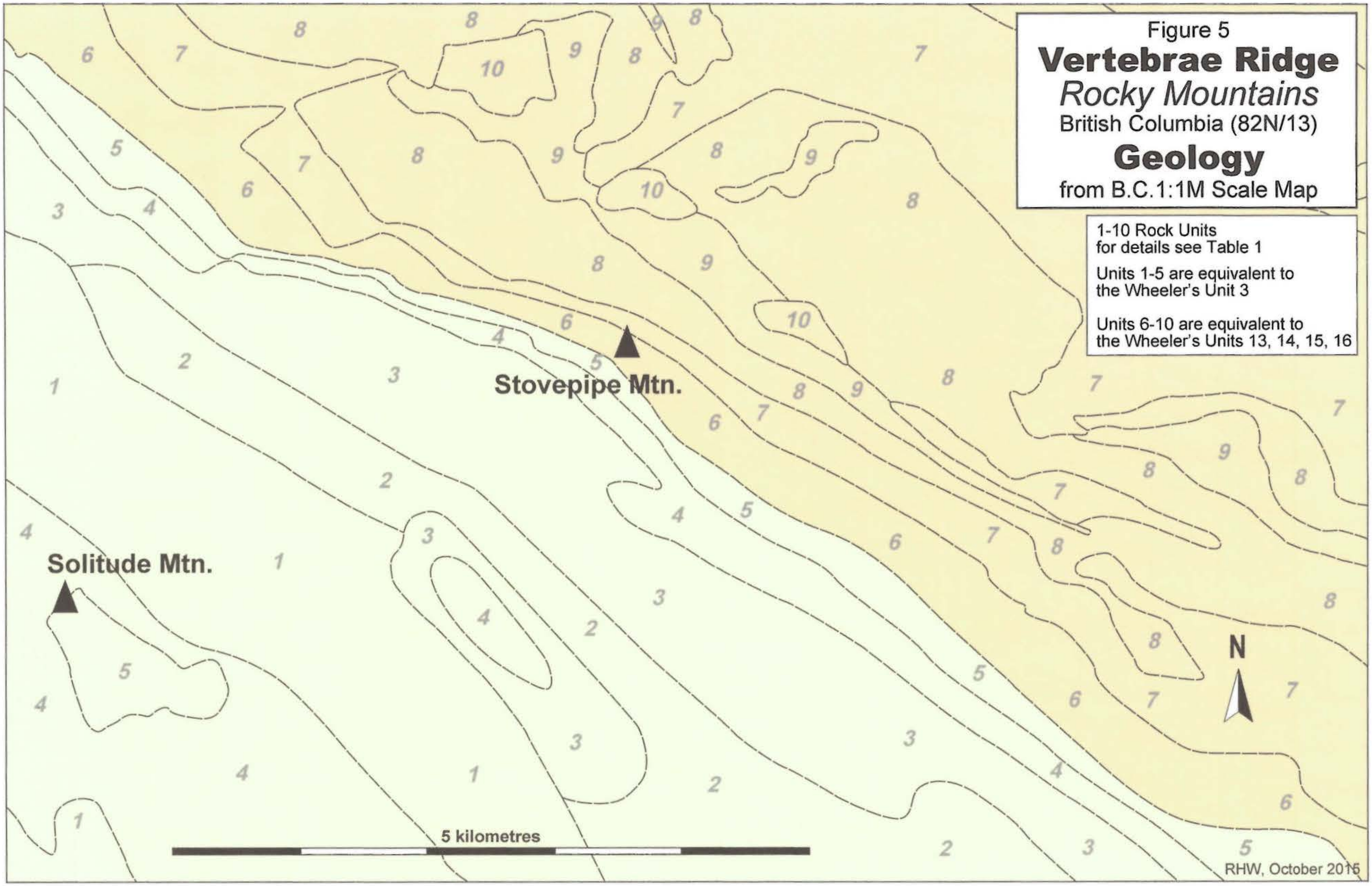


Figure 5
Vertebrae Ridge
Rocky Mountains
British Columbia (82N/13)
Geology
from B.C.1:1M Scale Map
1-10 Rock Units
for details see Table 1
Units 1-5 are equivalent to the Wheeler's Unit 3
Units 6-10 are equivalent to the Wheeler's Units 13, 14, 15, 16
Stovepipe Mtn.
Solitude Mtn.
N
5 kilometres
RHW, October 2015

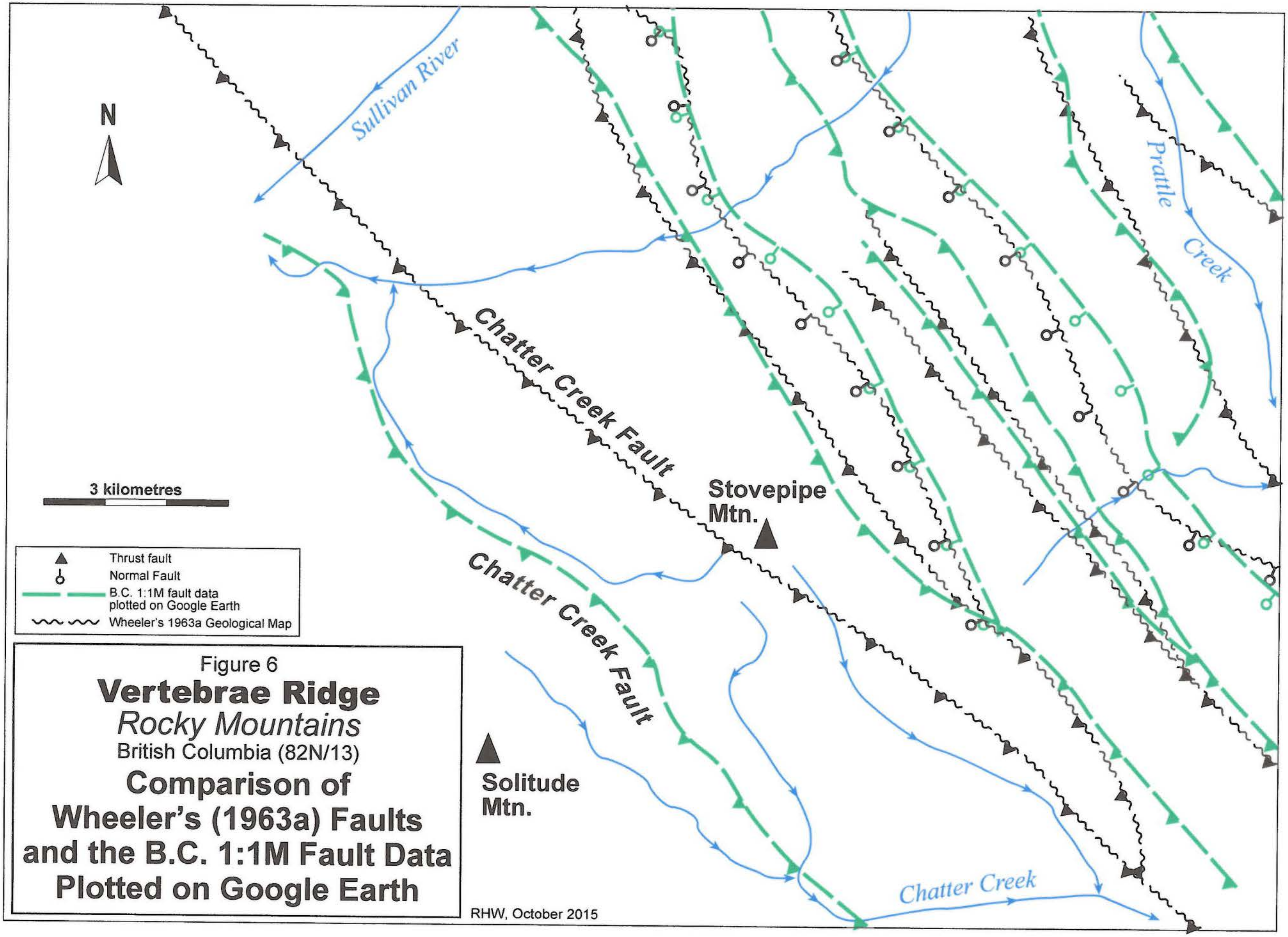


Figure 6

Vertebrae Ridge

Rocky Mountains

British Columbia (82N/13)

Comparison of Wheeler's (1963a) Faults and the B.C. 1:1M Fault Data Plotted on Google Earth

RHW, October 2015

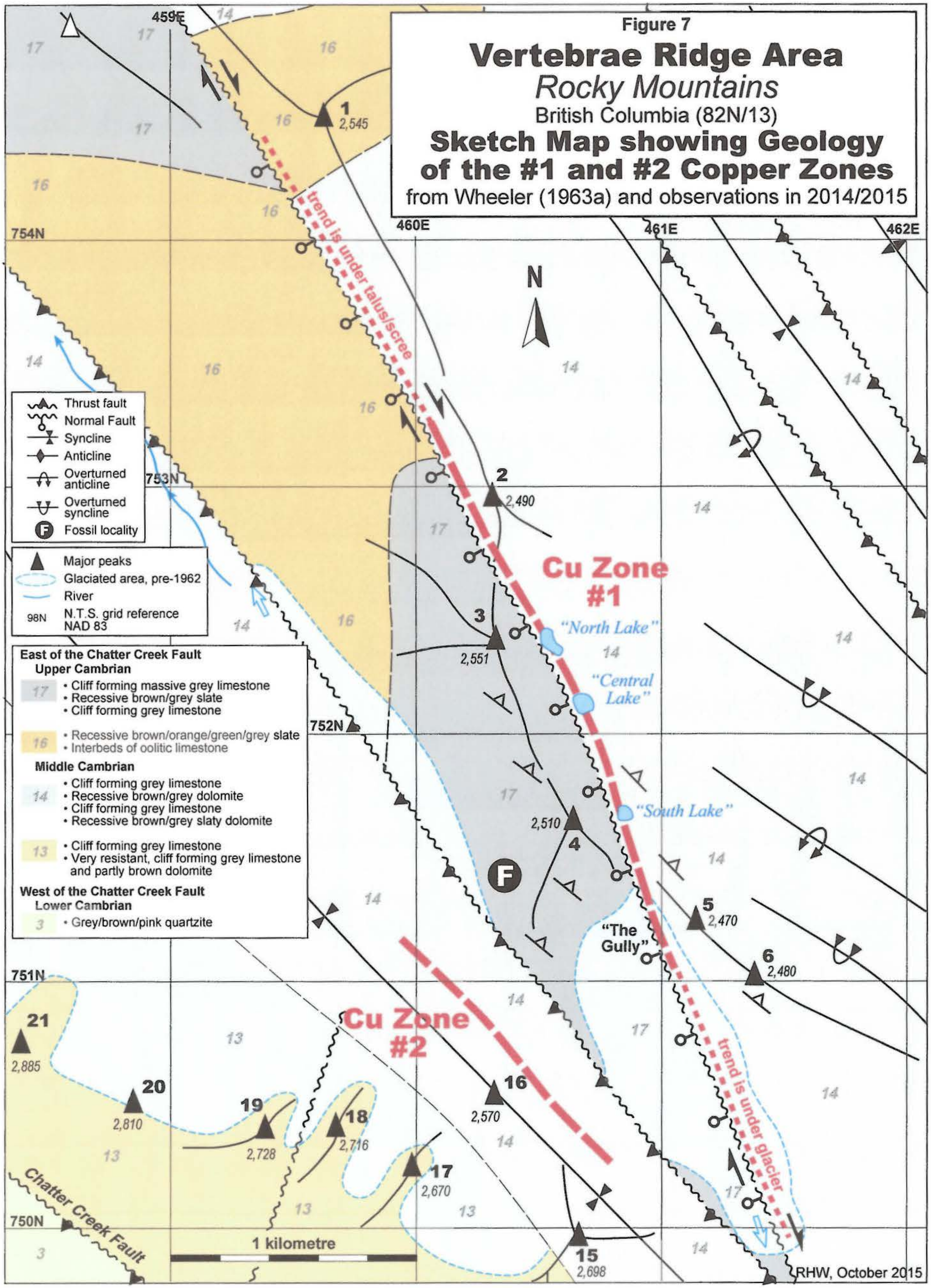


Figure 7
Vertebrae Ridge Area
Rocky Mountains
British Columbia (82N/13)
Sketch Map showing Geology of the #1 and #2 Copper Zones
from Wheeler (1963a) and observations in 2014/2015
Thrust fault
Normal Fault
Syncline
Anticline
Overturned anticline
Overturned syncline
Fossil locality
Major peaks
Glaciated area, pre-1962
River
98N N.T.S. grid reference NAD 83
East of the Chatter Creek Fault
Upper Cambrian
17 • Cliff forming massive grey limestone • Recessive brown/grey slate • Cliff forming grey limestone
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Middle Cambrian
14 • Cliff forming grey limestone • Recessive brown/grey dolomite • Cliff forming grey limestone • Recessive brown/grey slaty dolomite
13 • Cliff forming grey limestone • Very resistant, cliff forming grey limestone and partly brown dolomite
West of the Chatter Creek Fault
Lower Cambrian
3 • Grey/brown/pink quartzite
459E
460E
461E
462E
754N
753N
752N
751N
750N
N
trend is under talus/scree
trend is under glacier
Cu Zone #1
Cu Zone #2
"North Lake"
"Central Lake"
"South Lake"
"The Gully"
Chatter Creek Fault
1 kilometre
1 2,545
2 2,490
3 2,551
4 2,510
5 2,470
6 2,480
15 2,698
16 2,570
17 2,670
18 2,716
19 2,728
20 2,810
21 2,885
RHW, October 2015

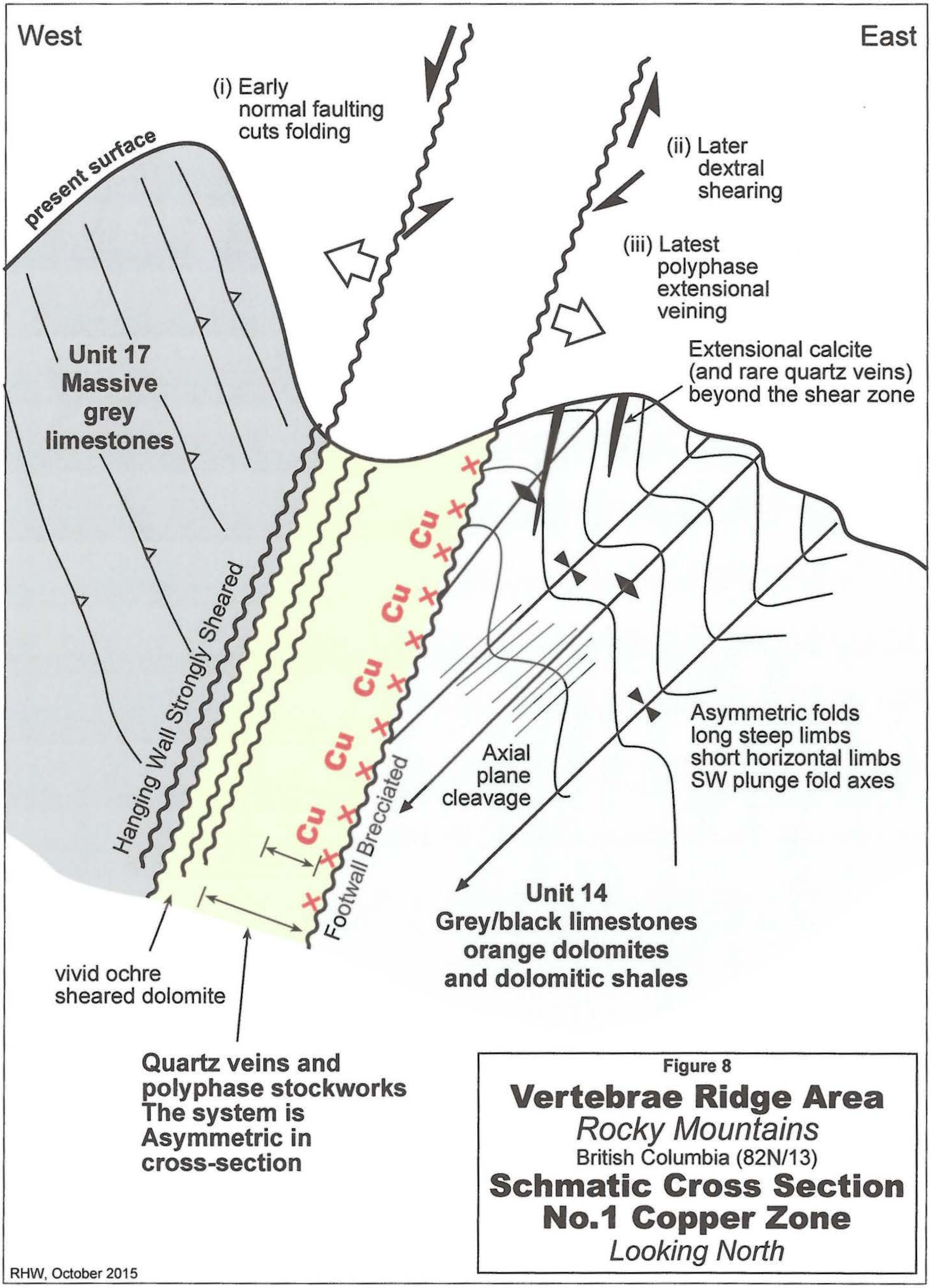


Figure 8

Vertebrae Ridge Area

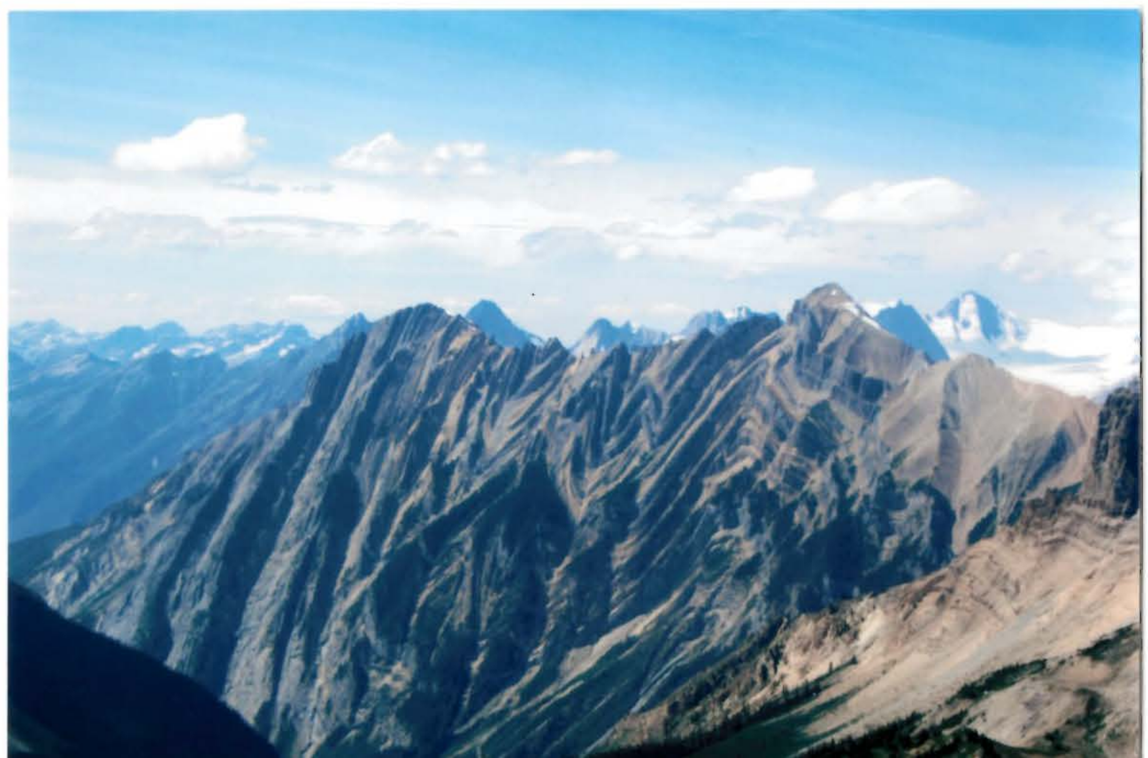
Rocky Mountains

British Columbia (82N/13)

Schmatic Cross Section

No.1 Copper Zone

Looking North

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