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2019

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Cover Illustration:
Exposures of the Sekwi Formation, Bonnet Plume Lake map area (NTS 106B), northern Mackenzie Mountains. Contact with the underlying Backbone Ranges Formation is at the base of the cliff at the lower left corner of the mountain. The overlying Hess River Formation is present above the dip slope at top of mountain. The “quartzite marker” (see report) forms a dark reddish-brown cliff band low on the mountain in the foreground. Photograph taken looking to the east, 20 July 2017. Coordinates: 64°36′52”N, 130°30′15”W. Photographer: K.M. Fallas.

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Publications in this series have not been edited; they are released as submitted by the author.

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INTRODUCTION

The Sekwi Formation (Handfield, 1968) is a widely distributed lower Cambrian unit in the Mackenzie Mountains (Figure 1). It is heterolithic, dominated by limestone and dolostone, but also containing significant volumes of sandstone and mudrock. It also is a significant host of Zn-Pb mineralization in the Mackenzie Mountains (Dewing et al., 2006; Ootes et al., 2011; Fischer, 2012) and is one of the more thoroughly studied map units in that region. Of particular note is the series of reports by Fritz (1972, 1976, 1978, 1979a, b) that described numerous measured sections through the Sekwi Formation and documented the trilobite biostratigraphy of the unit in considerable detail. Several theses and other publications have discussed the sedimentology, stratigraphy, and economic mineralogy of the Sekwi Formation (Krause, 1979; Krause and Oldershaw, 1979; Dilliard, 2006; Dilliard et al., 2007, 2010; Fischer, 2012). For a recent overview of the Sekwi Formation, see Fischer and Pope (2011). The present report draws on the extensive published record of measured sections for the Sekwi Formation to provide a set of isopach maps for the unit, for the biozones contained within it, and for a key marker interval.

STRATIGRAPHY

Figure 2 summarizes the early Cambrian lithostratigraphy and biostratigraphy of the Mackenzie Mountains. Throughout much of the Mackenzie Mountains, the Sekwi Formation lies gradationally upon fine-grained siliciclastics of the sub-trilobite Cambrian Vampire Formation (Fritz, 1982). In such locations, the Sekwi Formation preserves three Cambrian biozones: in ascending order, the *Fallotaspis* Zone, *Nevadella* Zone, and *Bonnia-Olenellus* Zone (Fritz 1972). These biozones place the formation in Stages 3 and 4 of Cambrian Series 2 (Peng et al., 2012). At the northern and eastern limits of its extent, the Sekwi Formation lies sharply upon the quartzite-dominated upper member of the Ediacaran-Cambrian Backbone Ranges Formation (Gabrielse et al., 1973) and the contact between the two units may be disconformable (R.B. MacNaughton and K.M. Fallas, work in progress).

In western exposures, Sekwi Formation is conformably and diachronously overlain by dark-weathering calcareous shale and lesser limestone of the Hess River Formation (e.g. Cecile, 1982). To the south, lateral equivalents of the Hess River Formation, including the Rockslide Formation (nodular limestone and shale) and Avalanche Formation (dolostone, locally oncolitic), lie conformably upon the Sekwi Formation (Gabrielse et al., 1973). In easternmost localities, Sekwi Formation is overlain disconformably by Furongian to Early Ordovician strata (see review by Fischer and Pope, 2011).

Although member-scale subdivisions of the Sekwi Formation have been proposed, their utility for isopach preparation is limited. The dolomite-dominated Brintnell Member (Gabrielse et al., 1973) appears to be present only in the southern part of the Sekwi Formation's area of occurrence. The so-called "Swiss-cheese limestone" (Green and Roddick, 1961) was treated as an informal basal member by Gabrielse et al. (1973) but is not present consistently from section to section (Fritz, 1976). A three-fold informal subdivision proposed by Fischer and Pope (2011) consists, in ascending order, of the "lower carbonate", "quartz-sandy", and "upper carbonate" members. Although these units can be recognized widely, the quartz-sandy member loses its distinctiveness to the north and west, and the members may not be applicable in the southeasternmost extent of the Sekwi Formation (Fischer and Pope, 2011).

Preliminary attempts have been made to document allostratigraphic subdivisions within the Sekwi Formation. Fritz (1976, 1978, 1979a) prepared fence diagrams and subdivided strata of the Sekwi Formation and underlying siliciclastic units into "grand cycles", following the example of Aitken (1966), but these packages should be restudied in the light of modern sequence-stratigraphic principles. A sequence-stratigraphic subdivision for the lower part of the Sekwi Formation was published by Dilliard et al. (2010), based on an east-west transect of measured sections in Sekwi Mountain map area (NTS 105P). However, the lateral extent of the sequences has not been documented, nor has an account of the sequence stratigraphy of the upper part of the Sekwi Formation been published.

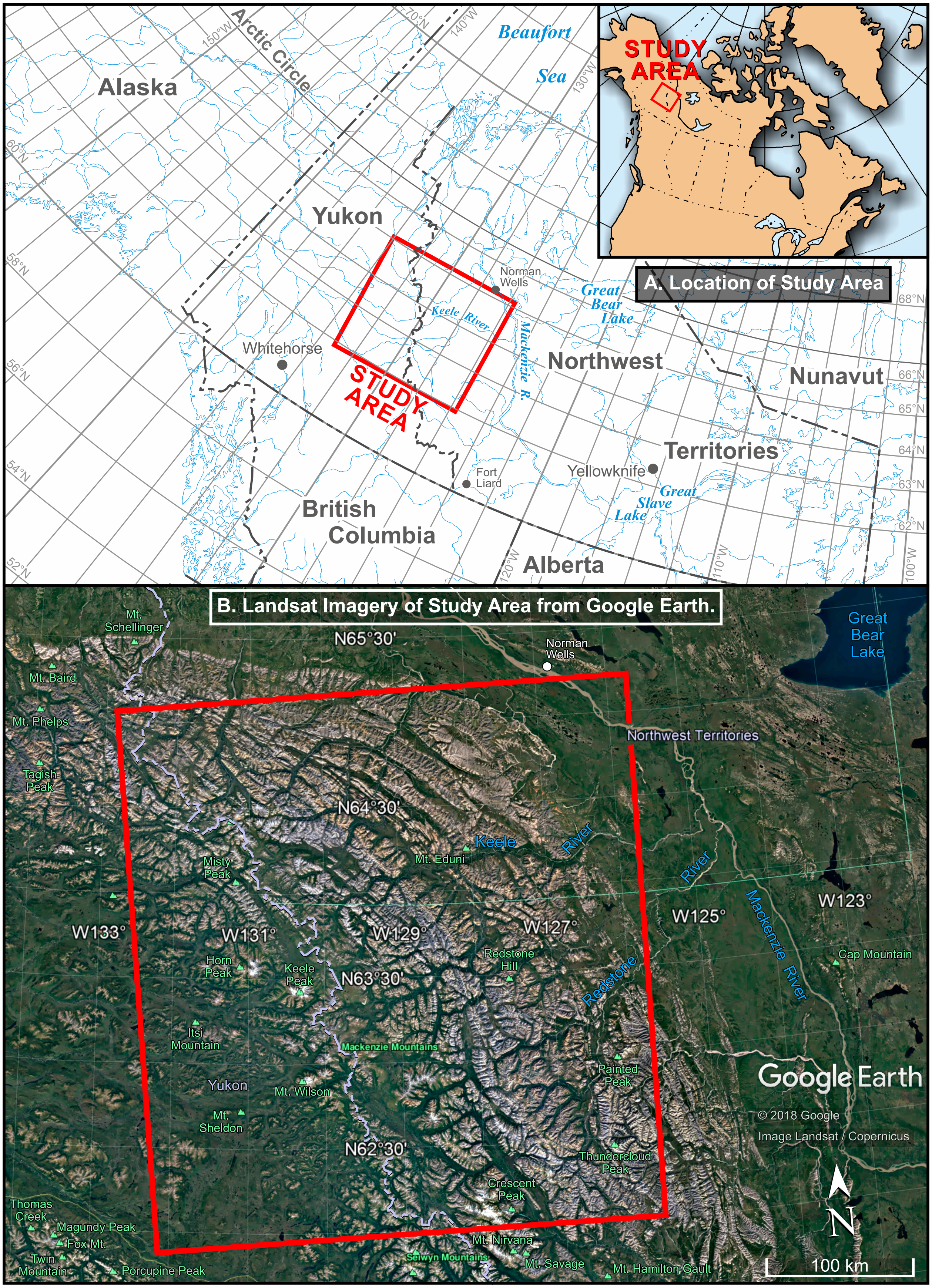


Figure 1. Location Map **(A)** and Landsat Image **(B)** of the Study Area.

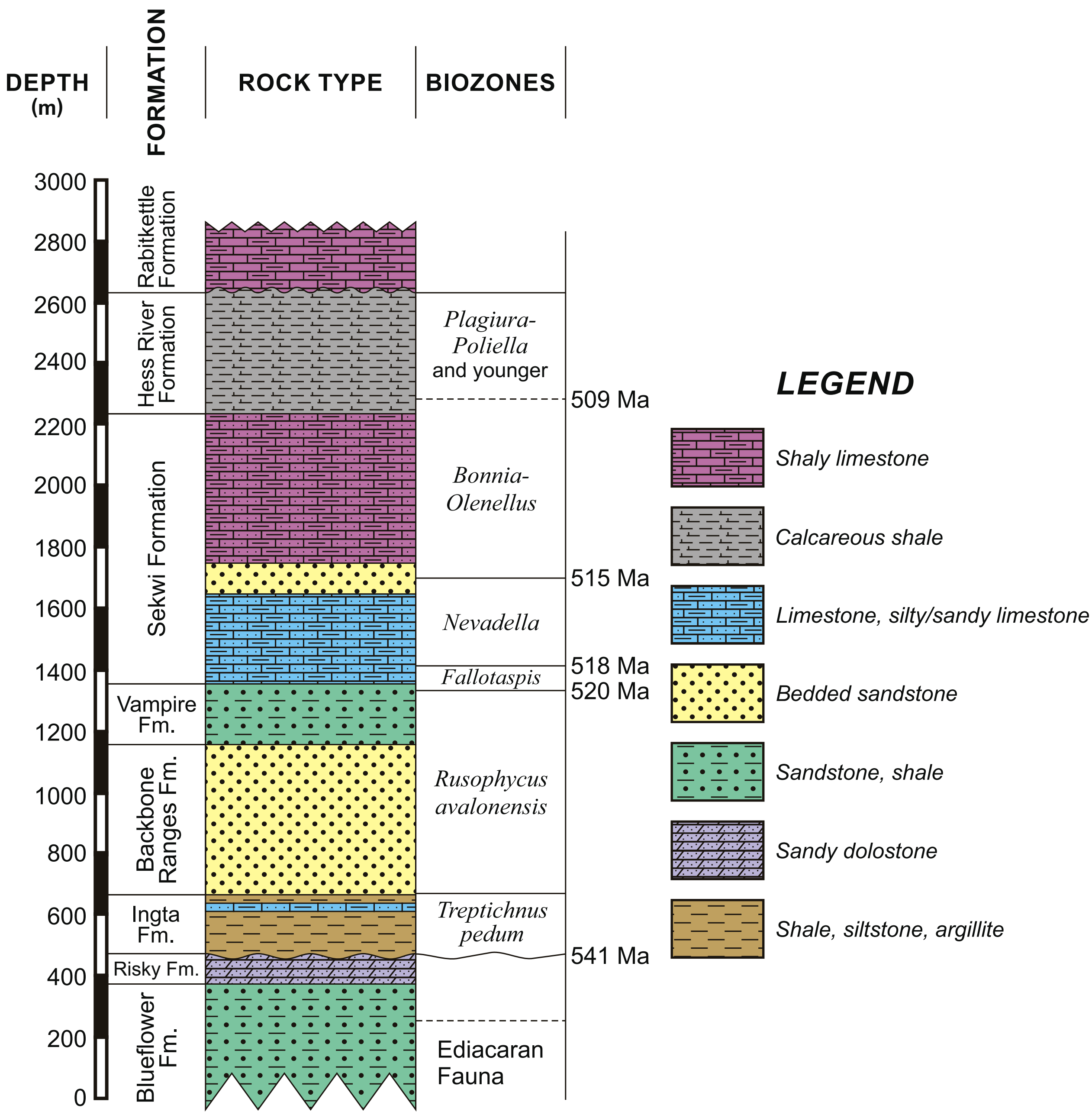


Figure 2. Lithostratigraphy and biostratigraphy of the Ediacaran and early Cambrian, Mackenzie Mountains, Northwest Territories. Biozonation shown to right of diagram. Diagram based on information from Fritz (1972), Cecile (1981), MacNaughton et al. (1997, 2000), and Dilliard et al. (2010).

In light of these limitations on the internal lithostratigraphic and allostratigraphic subdivisions of the Sekwi Formation, we have prepared isopach maps based primarily on the unit's well-documented biozones. These at present are probably the most robust means of subdividing the Sekwi Formation, although the possibility of facies control on first appearances of zone taxa must be acknowledged, and see below under "Procedures" for additional caveats. We also have prepared an isopach map for the thickness of a "quartzite marker" (an accumulation of pure quartz arenite) that lies at or near the boundary between the *Nevadella* Zone and *Bonnia*-*Olenellus* Zone, locally immediately above a karst surface (Krause, 1979; Fritz, 1979a) that Dilliard et al. (2010) interpreted as a sequence boundary. The quartzite marker is at roughly the same level as the quartz-sandy member of Fischer and Pope (2011), but the latter unit is markedly more heterolithic, locally including significant volumes of siltstone. By way of comparison with the other lithostratigraphic subdivisions of Fischer and Pope (2011), the lower carbonate member corresponds to the upper part of the *Fallotaspis* Zone and nearly the entirety of the *Nevadella* Zone, whereas the upper carbonate member essentially corresponds to that part of Sekwi Formation that lies within the *Bonnia*-*Olenellus* Zone (Fritz, 1972).

DATASET

Data used for the Sekwi Formation isopach maps were compiled from multiple sources that presented partial or complete sections through the unit. The primary sources were reports by Fritz (1976, 1978, 1979a) wherein 36 measured sections were presented. Other sources include GSC reports, Ph.D. theses, journal publications, and unpublished data. A full breakdown of control points and data sources for each isopach map can be found in the Appendix, a Microsoft® Office Excel® Open XML Format Spreadsheet file.

PROCEDURES

The map datum used for all isopach maps was NAD83; control points recorded originally in NAD27 were projected in NAD83 for consistency. The precision of coordinates from the data sources was variable. All coordinates were converted to decimal degrees. For sources in which only estimated coordinates were provided, more accurate and precise locations were inferred based on exposures visible in satellite imagery and comments provided by the original authors (e.g. if a section were measured near a particular bend of a given river).

Many sections were partial, providing a minimum thickness. Sections identifying truncation of the Sekwi Formation by faults or unconformities were also treated as incomplete, again providing a minimum thickness. Minimum thickness values are shown on the maps as the thickness with a '+' added; such points were used only to constrain the position of isopach lines of lesser value than the reported thickness of the incomplete section. The isopach maps for total Sekwi thickness (Figures 3 and 4) were the only maps to include all partial and full sections measured in the area. In Figures 3 and 4, incomplete thicknesses were used to control the isopachs, but for visual clarity not all incomplete data points have been shown. Many of the measured sections documented by Fritz (1976, 1978, 1979a) were measured in segments. In such cases, the segments have been grouped into composite sections. Imperial units used in older reports were converted into metric units.

Biozone thicknesses in the Sekwi Formation were sourced from Fritz (1976, 1978, 1979a), Dilliard et al. (2010), and an unpublished section measured by R.B. MacNaughton and K.M. Fallas in 2008. These sources provided sections that encompassed the entire thickness of the Sekwi Formation, with sufficiently detailed fossil sampling to delineate biozones. In some sections, Fritz (1976, 1978, 1979a) extrapolated biozone boundary positions into sections where tight fossil constraints were lacking. In these cases, we measured the positions of boundaries directly from his graphical stratigraphic columns.

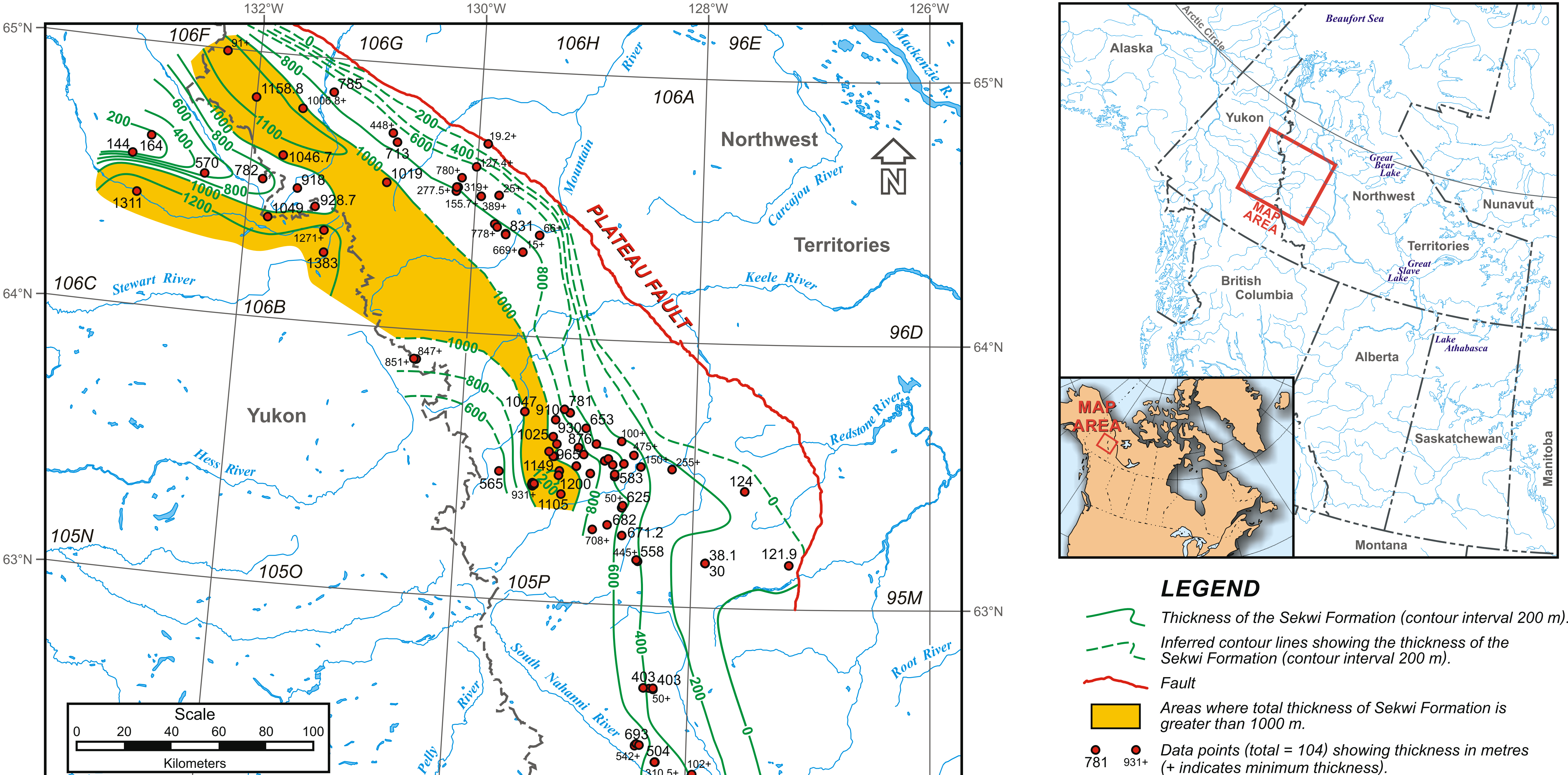
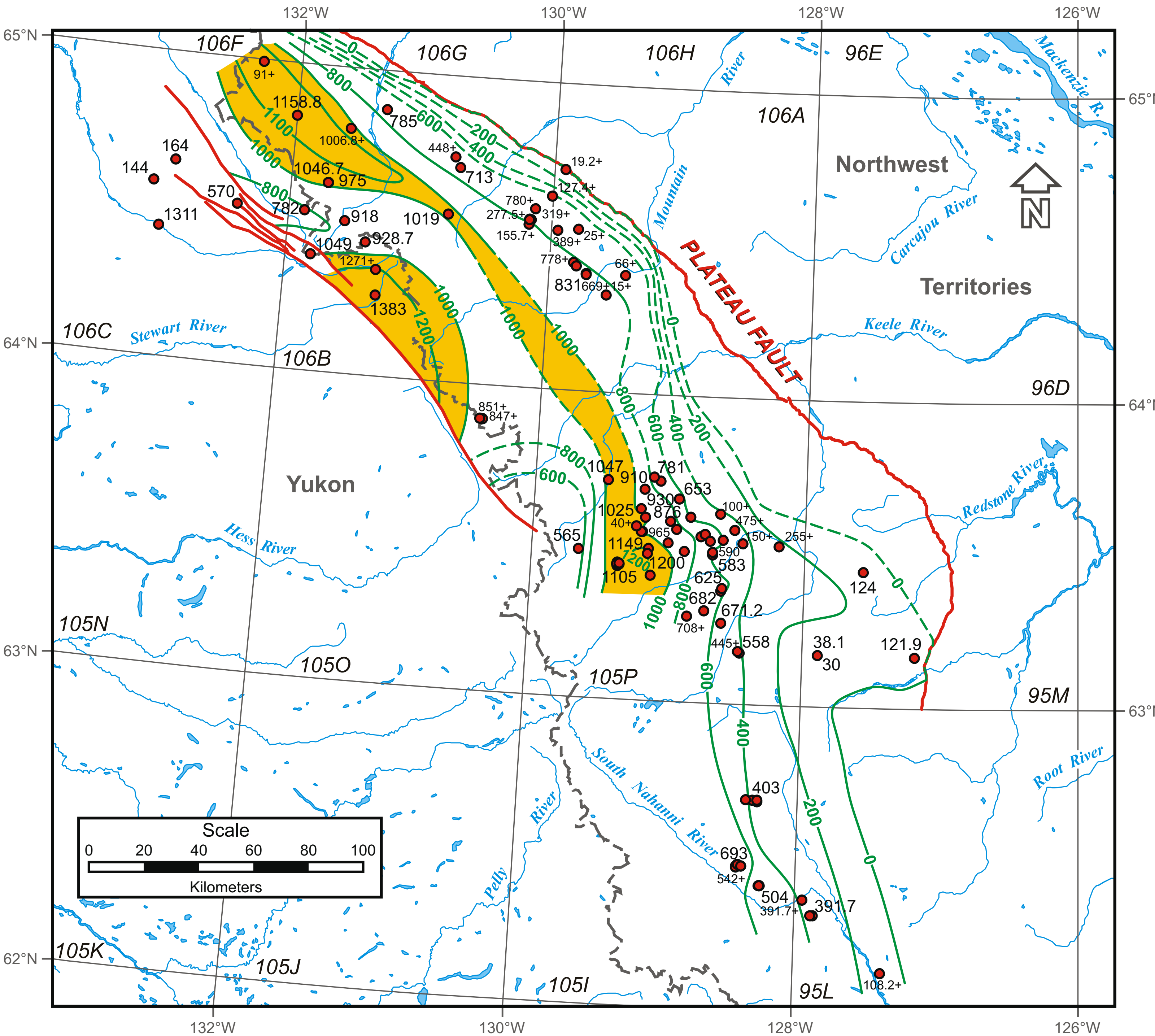
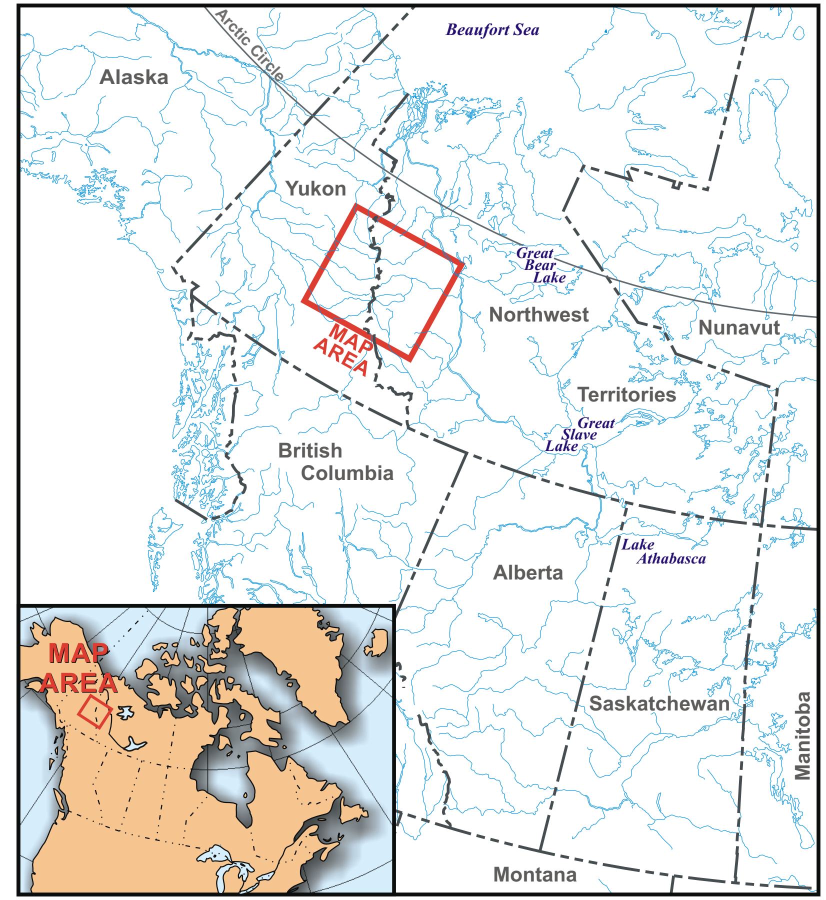


Figure 3. Isopach map of total thickness of the Sekwi Formation, without Blusson's (1974) mapped faults. Due to tight contouring near the Plateau Fault, a 200 m contour interval was used to preserve visual clarity on the map. Areas where total thickness is greater than 1000 m are highlighted in yellow. Isopachs based on 104 data points.





LEGEND

Thickness of the Sekwi Formation (contour interval 200 m).

Inferred contour lines showing the thickness of the Sekwi Formation (contour interval 200 m).

Fault

Areas where total thickness of Sekwi Formation is greater than 1000 m.

558 445+ *Data points (total = 104) showing thickness in metres (+ indicates minimum thickness).*

Figure 4. Isopach map of total thickness of the Sekwi Formation, incorporating faults mapped by Blusson (1974) near the Yukon – Northwest Territories border. Due to tight contouring near the Plateau Fault, a 200 m contour interval was used to preserve visual clarity on the map. Areas where total thickness is greater than 1000 m are highlighted in yellow. Isopachs based on 104 data points.

Quartzite marker thicknesses were sourced primarily from Fritz (1976, 1978, 1979a), except for a small number of sections that provided zero values (see Appendix). Quartzites *sensu stricto* (i.e. pure, well-cemented quartz arenites) documented by Fritz within 30 metres of the *Nevadella* Zone – *Bonnia-Olenellus* Zone boundary were selected for isopach mapping. Most such occurrences were at or below the boundary. Further comments on the quartzite marker, and possible neighboring lithologies of interest, may be found in the Appendix.

ISOPACH MAPS

Isopach maps were prepared for total thickness of the Sekwi Formation thickness, biozone thicknesses (*Fallotaspis* Zone, *Nevadella* Zone, and *Bonnia-Olenellus* Zone), and quartzite marker thickness. All maps show the trace of the Plateau Fault – a major, regionally extensive structure (MacNaughton et al., 2008) that was used as an absolute zero-value contour. For ease of navigation, NTS map areas are labelled on each isopach map and will be referred to in the following text. Measured thickness values are shown in metres, as are the accompanying isopach line labels. The isopach maps are shown on a non-palinspastically restored base. Although Cretaceous and younger contraction and strike-slip motion have not been quantified for the region, Cecile (1982) argued these motions were minimal, not requiring palinspastic restoration of control points for isopach contouring of Cambrian strata. It may be noted, however, that closely spaced thrust faults, particularly in map sheet 106B, may be contributing to closely spaced isopach patterns in the northwest portion of each isopach map near the Plateau Fault.

Total thickness, Sekwi Formation (Figures 3 and 4)

Two isopach solutions were created for the total thickness of the Sekwi Formation, both of which display a dominant northwest-southeast trend. These maps compare isopachs created “as-is” (Figure 3) to isopachs created with faults originally mapped by Blusson (1974) parallel to the Yukon – Northwest Territories border in map sheets 106C, 106B, and 105O (Figure 4).

Both maps show the Sekwi Formation thickening southwestward, i.e. basinward, away from the Plateau Fault, and then apparently thinning along the boundary between 105O and 105P. Also, on both maps the central portion of 105P contains a local thick region, creating a “bulls-eye” pattern around a 1200 m-thick Sekwi Formation section.

On the “as-is” map (Figure 3), very tight contouring is required in the northwest portion of the study area, especially in 106C, to address a steep interpreted thickness gradient. In the northwest part of the map, a thin zone extends towards the southeast, and is defined by two thicker zones flanking it. Thickening in 106B appears to taper southeastward, although no control points are present to constrain this. The steepness of the thickness gradient raises the possibility of faults as an influence on the distribution of thickness data. Blusson (1974) mapped a number of faults in this region. Motion on some present-day faults during or shortly after deposition of Sekwi Formation is unknown, but when these faults are included in the isopach map (Figure 4), they cluster in the region of the steep thickness gradient. In the resulting map (Figure 4), some of the more extreme thickness variations are isolated in separate structural panels. The above-mentioned thin zone still appears, but shows less extreme thickness variations and may extend further to the southeast.

Fallotaspis Zone, Sekwi Formation (Figure 5)

Figure 5 illustrates thickness variations of that portion of the *Fallotaspis* Zone preserved in the lowermost part of the Sekwi Formation. Although *Fallotaspis* Zone trilobites locally are found in the uppermost part of the underlying Vampire Formation, the lithofacies in that unit are not favourable to their preservation. For this reason, the position of the biozone's lower boundary is almost certainly inconsistent, and it was deemed inadvisable to include the Vampire Formation in the isopach maps.

This isopach map should be viewed with caution for several reasons. First, the base of the Sekwi Formation is gradational where it overlies the Vampire Formation, generally placed at the first appearance of carbonate lithofacies. Such a contact may be diachronous and should not be viewed as a time-line. Second, in several sections, lack of fossils forced Fritz (1976, 1978, 1979a) to extrapolate the top of the *Fallotaspis* Zone; in some cases, his chosen position for the boundary shows no obvious correlation to changes in lithology. Dilliard et al. (2010) also dealt with tenuous boundaries for the *Fallotaspis* Zone, placing them where deemed appropriate given lithological changes. Third, in all but six sections the *Fallotaspis* Zone is less than 20 m thick.

Overall, the isopachs are regular, trending northwest-southeast, and thickening southwest away from the Plateau Fault, into a belt where the *Fallotaspis* Zone portion of the Sekwi Formation is more than 20 m thick. Southwest of this belt, preserved strata of *Fallotaspis* Zone within the Sekwi Formation apparently thin to zero, perhaps reflecting the potential diachroneity referred to in the previous paragraph. The 106B and 106C map areas contain control points constraining the thinning in the southwest direction. A single point from Dilliard et al. (2010) constrains the zero edge in the southwest quadrant of 105P. A northeastern zero edge is well defined between 95M and 105P, and also can be mapped in the northern part of 106B. This zero edge generally is associated with a region in which the Vampire Formation is absent and Sekwi Formation lies directly upon Backbone Ranges Formation, and so we hypothesize that it reflects non-preservation (or perhaps original non-deposition) of *Fallotaspis* Zone strata.

Two local thick sections (80.8 m, 25.0 m) create "bulls-eye" features in the 105P mapsheet. Another "bulls-eye" feature is in the 106B mapsheet, caused by a 42.7 m thick *Fallotaspis* Zone section. An additional section for which Dilliard et al. (2010) reported that the *Fallotaspis* Zone was 50 m thick is shown on the map but was not contoured as a "bulls-eye" due to uncertainties in the placement of the biozone boundary during the original study (M.C. Pope, pers. comm., 2018).

Nevadella Zone, Sekwi Formation (Figure 6)

Isopachs for the *Nevadella* Zone also trend generally northwest-southeast (Figure 6). The zero-value contour is constrained by the absence of the *Nevadella* Zone from the southeast portion of the map (i.e. from 95M). The zero-value contour is estimated to merge with the Plateau Fault trace in 106A. As for the *Fallotaspis* Zone (see above), we hypothesize that this zero-edge reflects non-deposition or erosion of *Nevadella* Zone strata to the east and northeast. Strata within the *Nevadella* Zone thicken to the southwest, reaching a maximum recorded value of 659 m in south-central 106B. The extent of this thick zone is unknown due to lack of control points. In central 105P, the thickest measured value for the *Nevadella* Zone is 449.6 m, and isopachs around that point delineate an elongated thick region that may continue to the northwest, roughly along trend with the "thick" in 106B. Contours thin to the southwest from this thickened area. This overall trend of southwestward thickening followed by southwestward thinning presumably reflects the deposition of slope clinoforms on a prograding margin, as documented in the lower Sekwi Formation by Dilliard et al. (2010). The east-central portion of 105P contains a relatively large 200-300 m thick zone that deflects contours to the east.

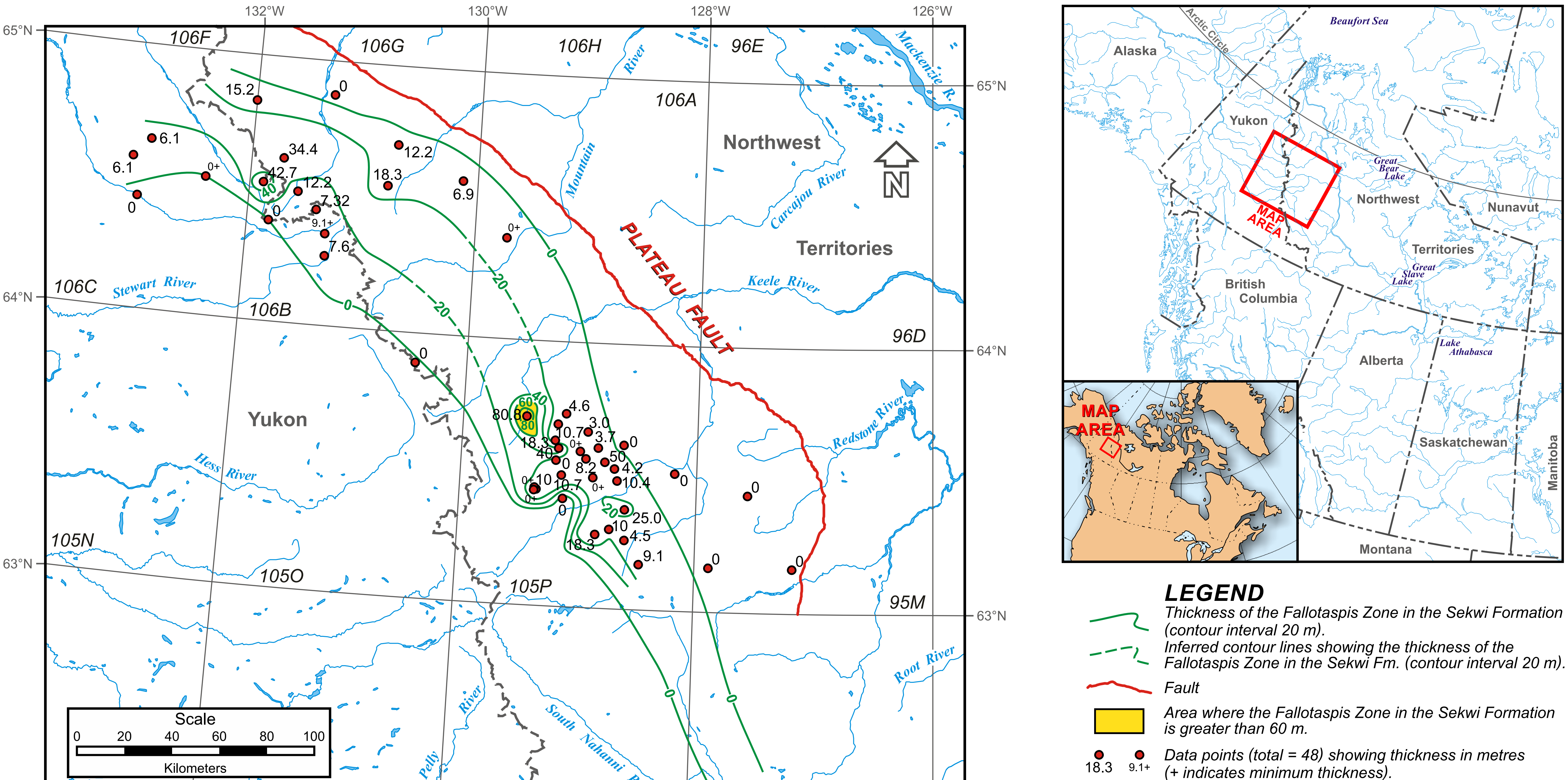
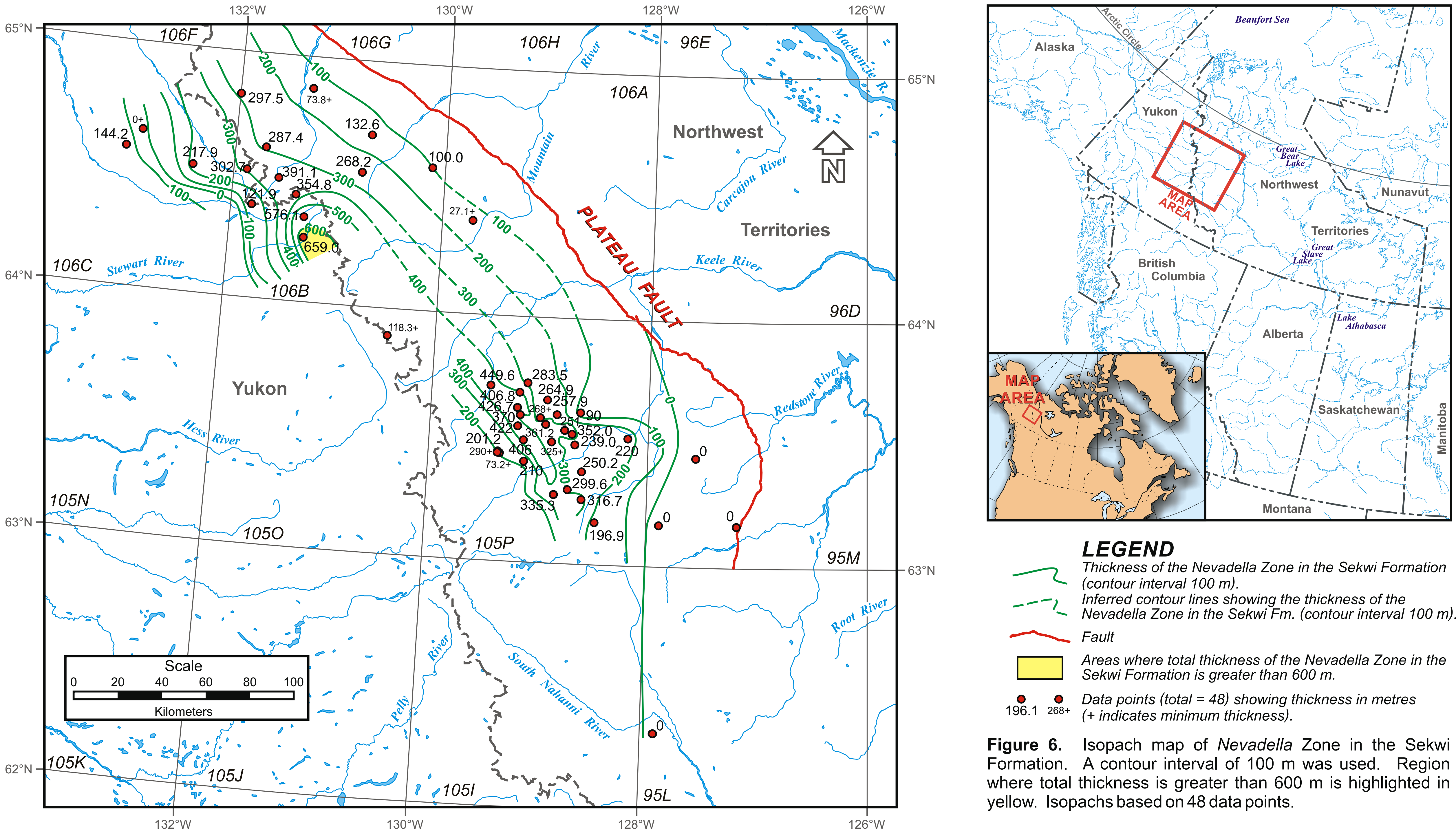


Figure 5. Isopach map of *Fallotaspis* Zone in the Sekwi Formation. A contour interval of 20 m was used. Region where total thickness is greater than 60 m is highlighted in yellow. Isopachs based on 48 data points.



LEGEND

Thickness of the Nevadella Zone in the Sekwi Formation (contour interval 100 m).

Inferred contour lines showing the thickness of the Nevadella Zone in the Sekwi Fm. (contour interval 100 m).

Fault

Areas where total thickness of the Nevadella Zone in the Sekwi Formation is greater than 600 m.

196.1 268+ *Data points (total = 48) showing thickness in metres (+ indicates minimum thickness).*

Figure 6. Isopach map of *Nevadella* Zone in the Sekwi Formation. A contour interval of 100 m was used. Region where total thickness is greater than 600 m is highlighted in yellow. Isopachs based on 48 data points.

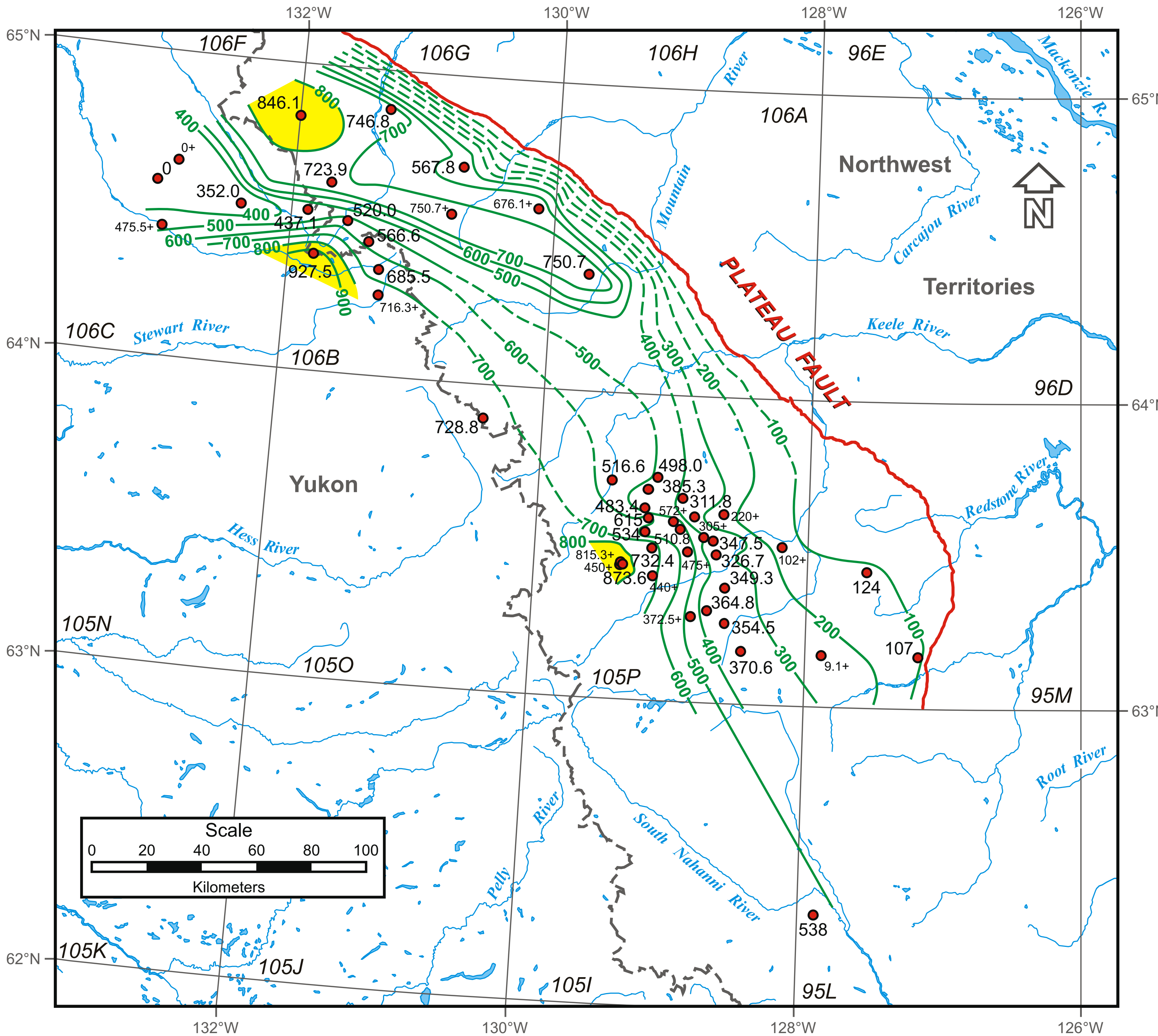
Bonnia-Olenellus Zone, Sekwi Formation (Figures 7 and 8)

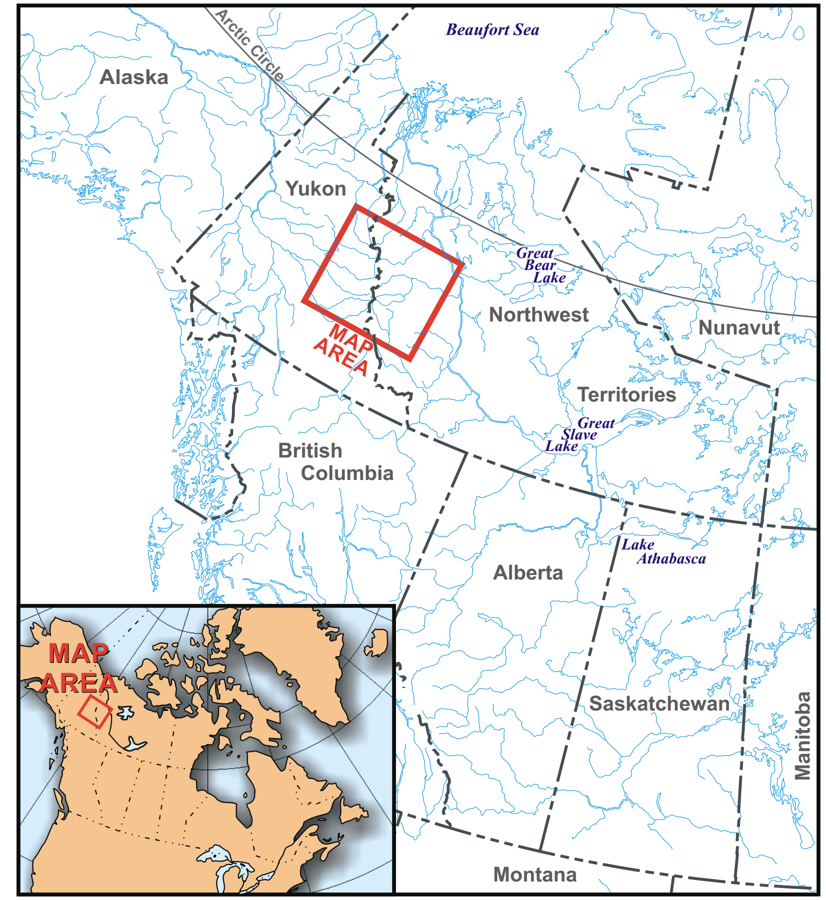
Isopach maps produced for the *Bonnia-Olenellus* Zone (Figures 7 and 8) document the thickness of the biozone in the Sekwi Formation only. Although the *Bonnia-Olenellus* Zone is completely contained within the Sekwi Formation in many sections, this biozone extends into overlying units (Hess River Formation = "post-Sekwi dark shale and platy limestone" of Fritz, 1976, 1978, 1979a) in localities within the ancient Misty Creek embayment (Cecile, 1982), implying that the upper contact of the Sekwi Formation is diachronous in that region. In view of the diachroneity of the Sekwi Formation's upper contact in the Misty Creek embayment, and of the potential for erosion of the upper part of the unit in its more northern and eastern occurrences (Fischer and Pope, 2011), isopach maps for *Bonnia-Olenellus* Zone only record total preserved thickness, and cannot be considered to contour the thickness of a genetic unit.

As for the isopach maps of total Sekwi Formation thickness (Figures 3 and 4), an "as-is" map was prepared (Figure 7), as was a map on which faults mapped by Blusson (1974) were used as a possible explanation of high variability in the thickness of the interval in the northwestern part of the study area (Figure 8). In both maps, contours show a broadly northwest-southeast trend. The southeast portions of the maps (Figures 7 and 8) are relatively regular, thickening towards the southwest away from the Plateau Fault, with local variations from the overall trend. Differences between the isopach maps are in the northwest, in map sheets 106C and 106B. On the "as-is" map (Figure 7), isopachs just south of the 846.1 m section require tight contouring over approximately 25 km. The southernmost isopachs of 106C and 106B also are very closely spaced and are concave and thicken to the south, wrapping around a 927.5 m thick *Olenellus* Zone section. When Blusson's (1974) mapped faults are incorporated (Figure 8), this 927.5 m thick section is, instead, part of a local fault panel. This allows for a less steep thickness gradient, showing a southwestward decrease from the 800 m zone, and truncating on the faults. However, the pattern created when faults from Blusson (1974) are incorporated shows an estimated 5000 km^2 rectangular area of 700 m thicknesses in the southeast quadrant of 106B and adjacent southwest quadrant of 106A, caused by the lack of control points in this area.

Quartzite marker, Sekwi Formation (Figure 9)

The thickness isopach for the quartzite marker also trends northwest-southeast (Figure 9). For the most part, the isopach patterns are regular, thickening southwestward from the Plateau Fault to a belt in which thicknesses are greater than 30 m, and thinning again to zero to the southwest from this belt. However, the northern part of 105P shows a "kidney" isopach shape, formed by the thicker sections of 45.7 m and 52.4 m. An eastern zero edge is well delineated between 95M and 105P. As for the *Fallotaspis* Zone and *Nevadella* Zone (see above), we hypothesize that this zero-edge reflects non-deposition or erosion of the quartzite marker to the east and northeast.





LEGEND

Thickness of the Bonnia-Olenellus Zone in the Sekwi Formation (contour interval 100 m).

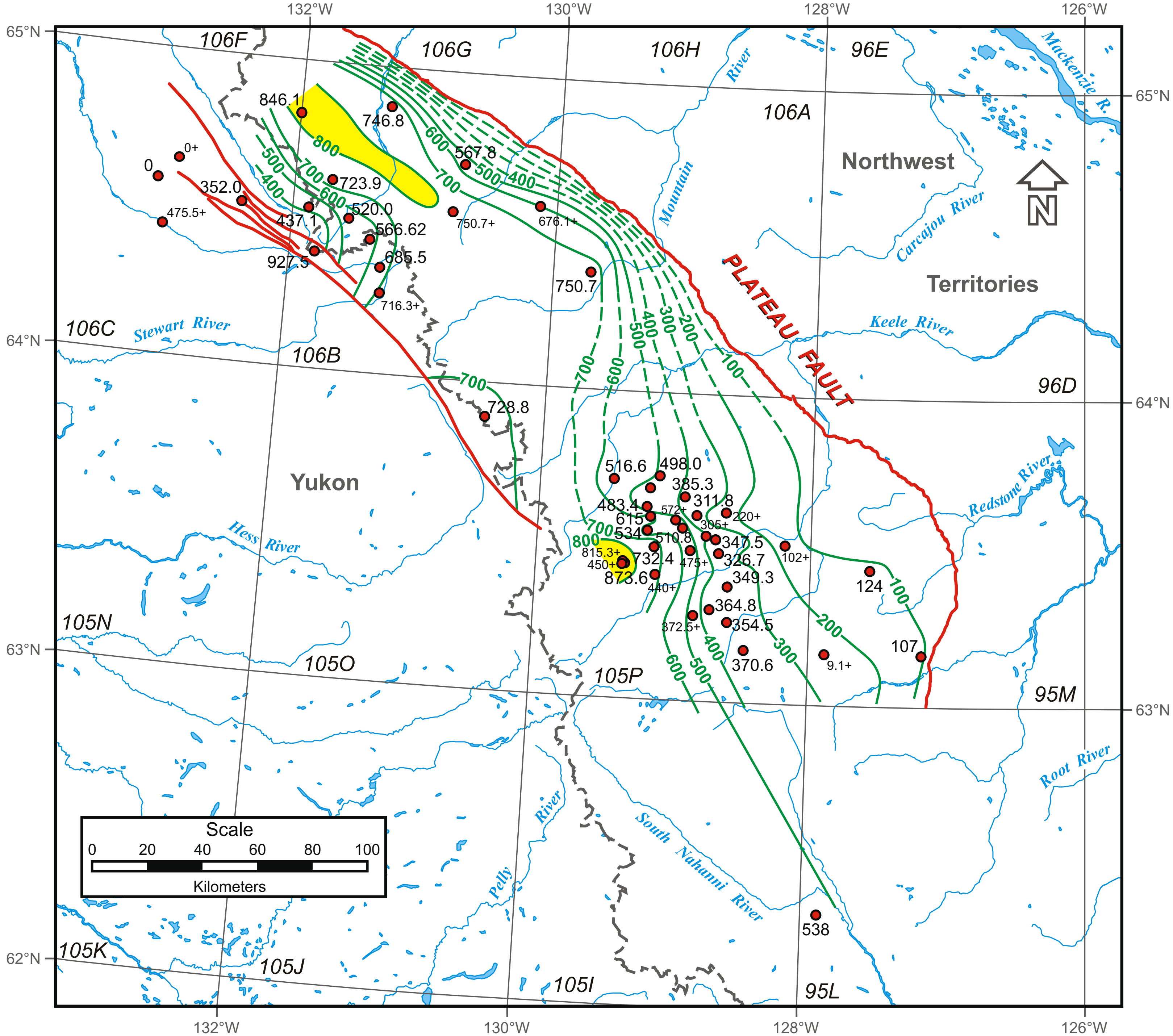
Inferred contour lines showing the thickness of the Bonnia-Olenellus Zone in the Sekwi Fm. (contour interval 100 m).

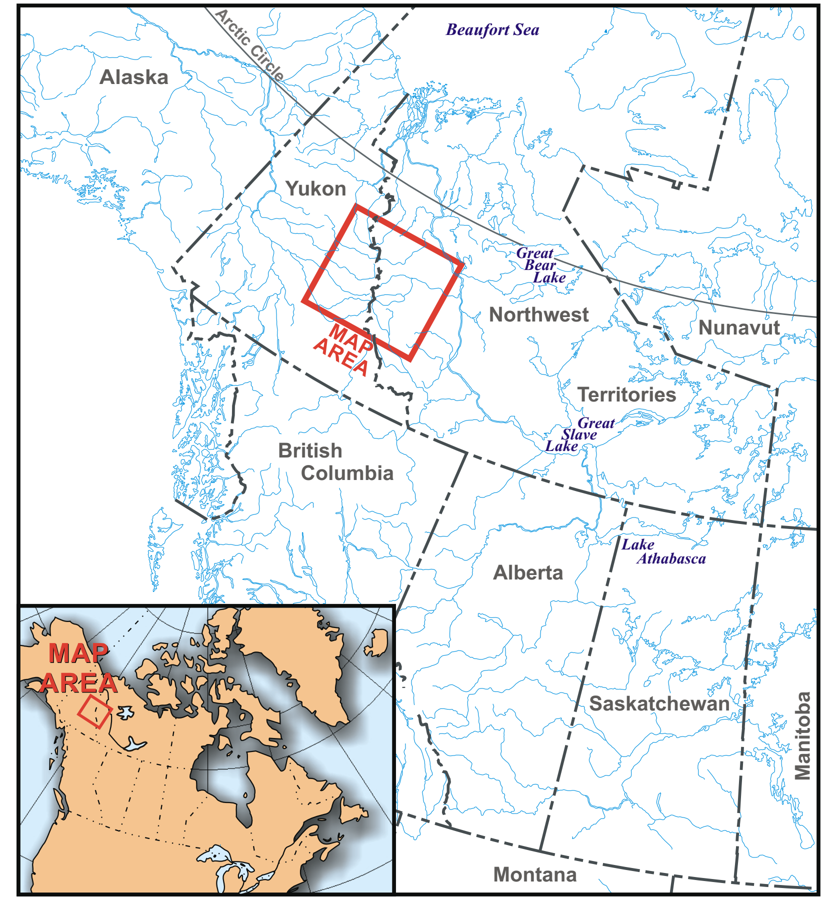
Fault

Areas where total thickness of the Bonnia-Olenellus Zone in the Sekwi Formation is greater than 800 m.

196.1 268+ Data points (total = 48) showing thickness in metres (+ indicates minimum thickness).

Figure 7. Isopach map of *Bonnia-Olenellus* Zone in the Sekwi Formation, without Blusson's (1974) mapped faults. Contour interval of 100 m was used. Regions where total thickness is greater than 800 m are highlighted in yellow. Isopachs based on 48 data points.





LEGEND

Thickness of the Bonnia-Olenellus Zone in the Sekwi Formation (contour interval 100 m).

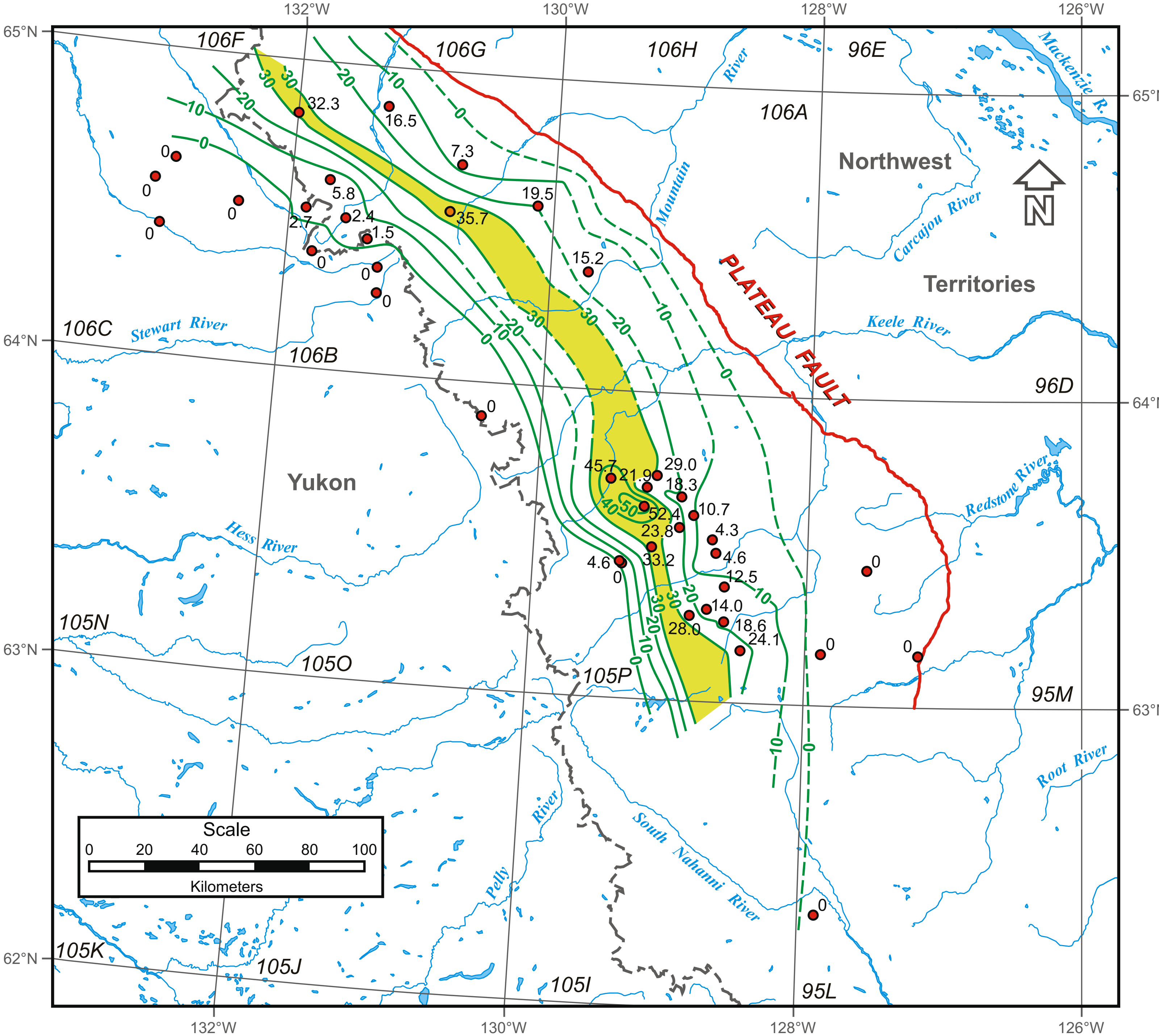
Inferred contour lines showing the thickness of the Bonnia-Olenellus Zone in the Sekwi Fm. (contour interval 100 m).

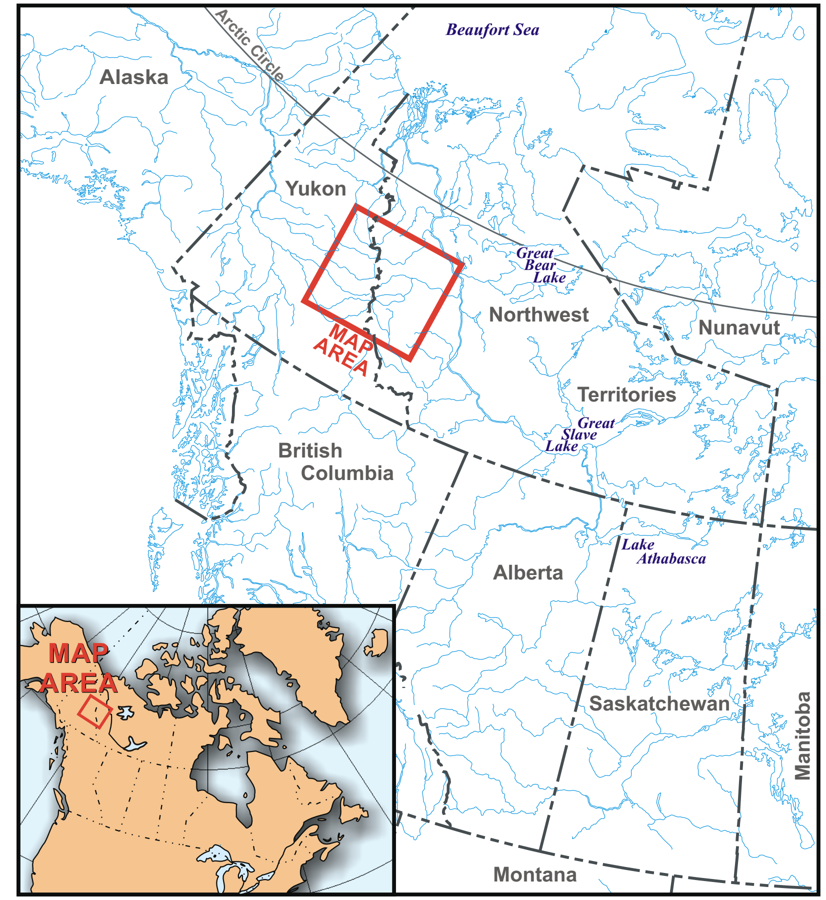
Fault

Areas where total thickness of the Bonnia-Olenellus Zone in the Sekwi Formation is greater than 800 m.

364.5 102+ Data points (total = 48) showing thickness in metres (+ indicates minimum thickness).

Figure 8. Isopach map of *Bonnia-Olenellus* Zone in the Sekwi Formation, incorporating faults mapped by Blusson (1974) near the Yukon – Northwest Territories border. Regions where total thickness is greater than 800 m are highlighted in yellow. Isopachs based on 48 data points.





LEGEND

Thickness of the "quartzite marker" in the Sekwi Formation (contour interval 30 m).

Inferred contour lines showing the thickness of "quartzite marker" in the Sekwi Fm. (contour interval 30 m).

Fault

Areas where total thickness of the "quartzite marker" in the Sekwi Formation is greater than 30 m.

10.7 Data points (total = 39) showing thickness in metres.

Figure 9. Isopach map of "quartzite marker" thickness in the Sekwi Formation. Regions where total thickness is greater than 30 m are highlighted in yellow. Isopachs based on 39 data points.

CONCLUSIONS

Detailed comments on the maps presented in this report will appear in future reports on the early Cambrian tectonostratigraphy of the Mackenzie Mountains. At present, it worth noting that all of the isopach maps prepared for this report have two features in common. First, isopachs generally trend northwest-southeast. Second, stratigraphic packages generally thicken southwestward away from the Plateau Fault. Lower packages (*Fallotaspis* Zone, *Nevadella* Zone, and the quartzite marker) reach a maximum thickness and then thin southwestward; this trend is less apparent for *Bonnia-Olenellus* Zone and total thickness of Sekwi Formation. This agrees well with westward or southwestward paleoslope directions as previously deduced for the Sekwi Formation (Dilliard et al., 2010) and underlying units such as the Backbone Ranges Formation (MacNaughton et al., 1997). A recommended avenue for future study is to expand to regional scale the sequence stratigraphic framework of Dilliard et al. (2010) for the lower part of the Sekwi Formation, and to prepare a sequence stratigraphic framework for the upper part of the formation as well. Additionally, the biostratigraphy of Fritz (1972, 1976, 1978, 1979a) should be reviewed and updated to reflect more recent developments in trilobite taxonomy, with the goal of improving constraints on the timing of the sequence stratigraphy.

ACKNOWLEDGEMENTS

We gratefully acknowledge the efforts of all the scientists whose data have informed this report, and especially the late Bill Fritz, whose stratigraphic documentation remains essential to understanding the geological evolution of the Mackenzie Mountains. Kelly Dilliard and Mike Pope are also thanked for their comments and suggestions during the preparation of this report. Tony Hamblin is thanked for his review of a draft version of the report. David Sargent is thanked for preparing the final version of the report for publication. This work is an output of the Geo-mapping for Energy and Minerals (GEM) project, and is part of the "Shield-to-Selwyn Geo-transect" activity of the Mackenzie Project.

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