Comparing petrographic and paleo-hydraulic methods for estimating of paleo-drainage basin size: an example from the Cretaceous and Tertiary Bonnet Plume Basin (NTS 106E) Yukon

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Summary

One of the key problems in understanding the evolution of terrestrial clastic depositional basins is estimating the size of the catchment area. This can be done using a variety of field observations of sedimentary structures, including cross-bed thickness and direction, channel and storey thickness and channel dimensions. These are used to predict flow velocity, mean annual and bank-full discharge, sinuosity, meander wavelength and ultimately drainage basin size. The mathematical products of these observations can be directly tested using petrographic analysis of sand and gravel grade clasts that have survived erosion and transport from the source area. This is especially practical in areas where the basin is surrounded by a broad range of rock types. In this study, predominantly fluvial strata from the upper and lower members of the Bonnet Plume Formation in the Bonnet Plume Basin (NTS 106E) (Fig 1-Left) were examined physically and petrographically to determine if these approaches produced comparable results. The basin is a structural and physiographic depression at the intersection of the Richardson Mountains and the Mackenzie Mountain front. It was formed in a trans-tensional setting at the same time as mountain building in western Canada. The basin fill has been divided into a lower and upper member of Cretaceous and Tertiary age (Fig 1-Right) and contains significant coal reserves (Long 1986), as well as having limited oil and gas potential (Lowey 2009).

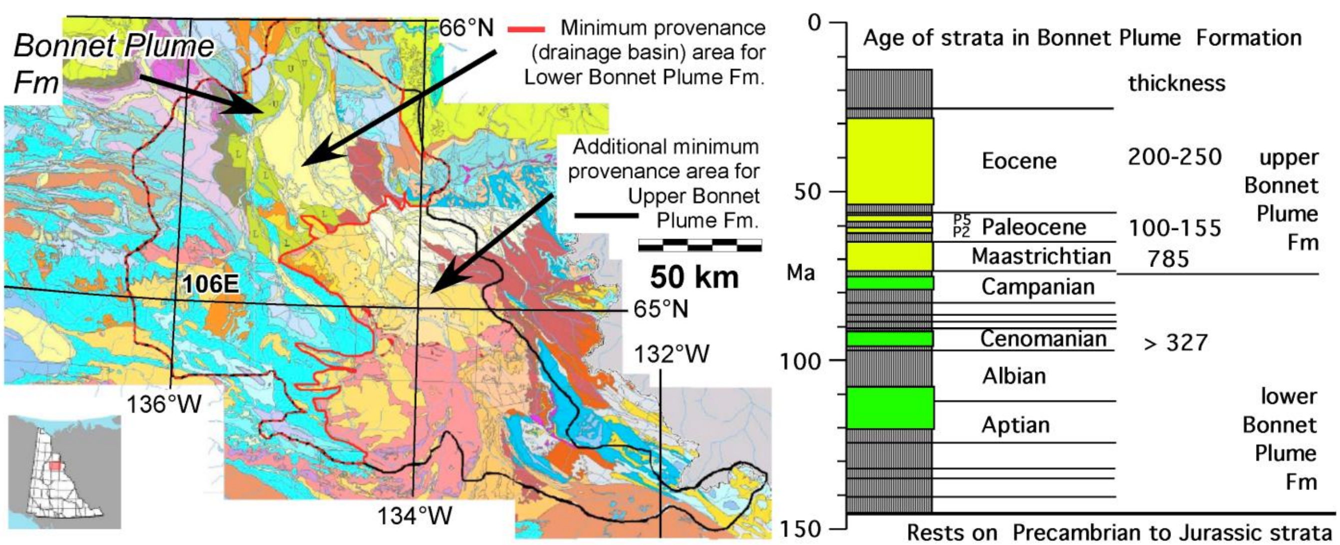

Figure 1. *Left*: Location of Bonnet Plume Basin (From Yukon Geological Survey website) with outlines of minimum required basin dimensions, for Lower (Red) and Upper (Red+Black) members of the Bonnet Plume Formation, based on petrography of chert and lithic grains. *Right*: Stratigraphic subdivisions of the Bonnet Plume Formation.

Petrographic study of chert and other resistate siliceous lithic fragments allows direct matching of grains to specific formations in the northern Mackenzie Mountains. The clast types include 18 varieties of chert, 12 varieties of resistant mudrock, and 20 other distinct lithotypes (Fig. 2 Left). Minimum drainage basin outlines in figure 1 were made by matching individual chert types to specific rock units. In order to accommodate potential source rocks, the lower member would have had a minimum area of ~11,200 km^2, while the upper member requires a catchment of at least 21,000 km^2 (Fig 1, Left). In contrast the average estimate of basin size using paleo-hydraulic analysis indicates a catchment area of 25,237 km^2 for the lower member, and 40,247 Km^2 for the upper member (Fig. 2 Upper right). This represents a 159% increase in catchment area between the lower and upper members. Slope estimates for both the upper and lower member are similar at 0.0004 m/m (Fig 2 Lower right).

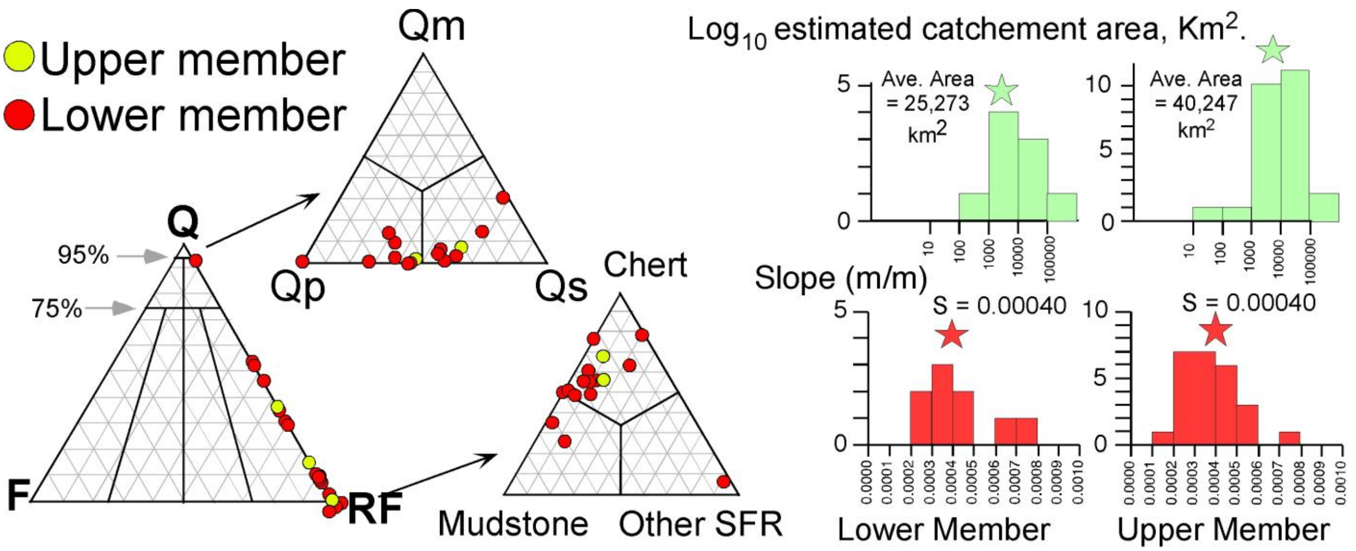

Figure 2 *Left:* Petrographic analysis of framework grains in the Bonnet Plume Formation. Q = Quartz, F = Feldspar, RF = rock fragments. Upper daughter triangle show plots of relative abundance of monocrystalline quartz (Qm), polycrystalline quartz (Qp), and strained quartz (Qs). Lower daughter plot shows relative abundance of chert, mudstone and other sedimentary rock fragments. *Right:* Top shows histogram (green) of paleo-hydraulic estimates of drainage basin size based on calculations of velocity, channel width and depth and sinuosity. Lower histogram (red) shows slope estimates from the same data sets.

Although the absolute estimates of basin size are not identical, with the paleo-hydraulic technique typically producing an estimate of twice that of the petrographic approach, the relative increase in basin size indicated by both methods is identical, indicating that both methods are viable. The petrographic technique may be expected to provide an under estimate of basin size, as it simply involves finding the closest potential source for each chert type. An additional petrographic test could be undertaken to see if zircon populations in both the upper and lower members show similar changes in predicted catchment basin size. In addition the paleo-hydraulic approach might be further refined by adapting calculations that incorporate climatically appropriate regional discharge estimates (cf. Davidson and Hartley, 2010).

References

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