Spatial variation of erosion rates and passive margin escarpment embayment from New England, NSW and Bellenden Ker, Queensland, Australia: an analysis using GIS and in-situ 10Be basin-wide cosmogenic nuclides

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Introduction

The eastern seaboard of Australia is characterized by a passive margin and a continental divide that separates the inland-draining rivers from those that drain to the Coral and Tasman seas (figure 1). Seaward of this divide lies the Great Escarpment (GE) of Australia that separates a moderate relief coastal plain from a low relief, high elevation plateau (figure 2). Quantifying the spatial variation of erosion rates from temperate New England (NE), New South Wales (NSW) and tropical Bellenden Ker (BK), Queensland (QLD), two regions with distinctly different climates and escarpment embayment (figures 1 and 2), could help constrain erosional controls that contribute to escarpment form. In this study, we compared forty detrital 10Be samples collected from sediments in the main trunk and tributaries of five major rivers: the Macleay, Bellinger, and Clarence in NE (figure 1A) and the Russel-Mulgrave and North Johnstone in BK (figure 1B). We then traced the escarpment position in ARCGIS and calculated a sinuosity ratio to better compare the degree of embayment in each region. Across both datasets we found that for NE, which has deep gorges cutting into the plateau, the degree of embayment was more than twice that of BK, where the escarpment position is significantly less embayed (ratio of .14 vs .35), and that erosion rates were significantly more variable (Figures 4 and 5). Erosion rates in low slope areas, such as on the plateau, were universally low with no other significant controlling factors. There was no correlation between erosion rates and catchment area, and that our data possibly echo previous studies that found that once mean rainfall passes an approximate threshold (around 2000mm/yr) basin characteristics that are known to control erosion rates, such as slope and lithology (figure 3), are possibly subdued.

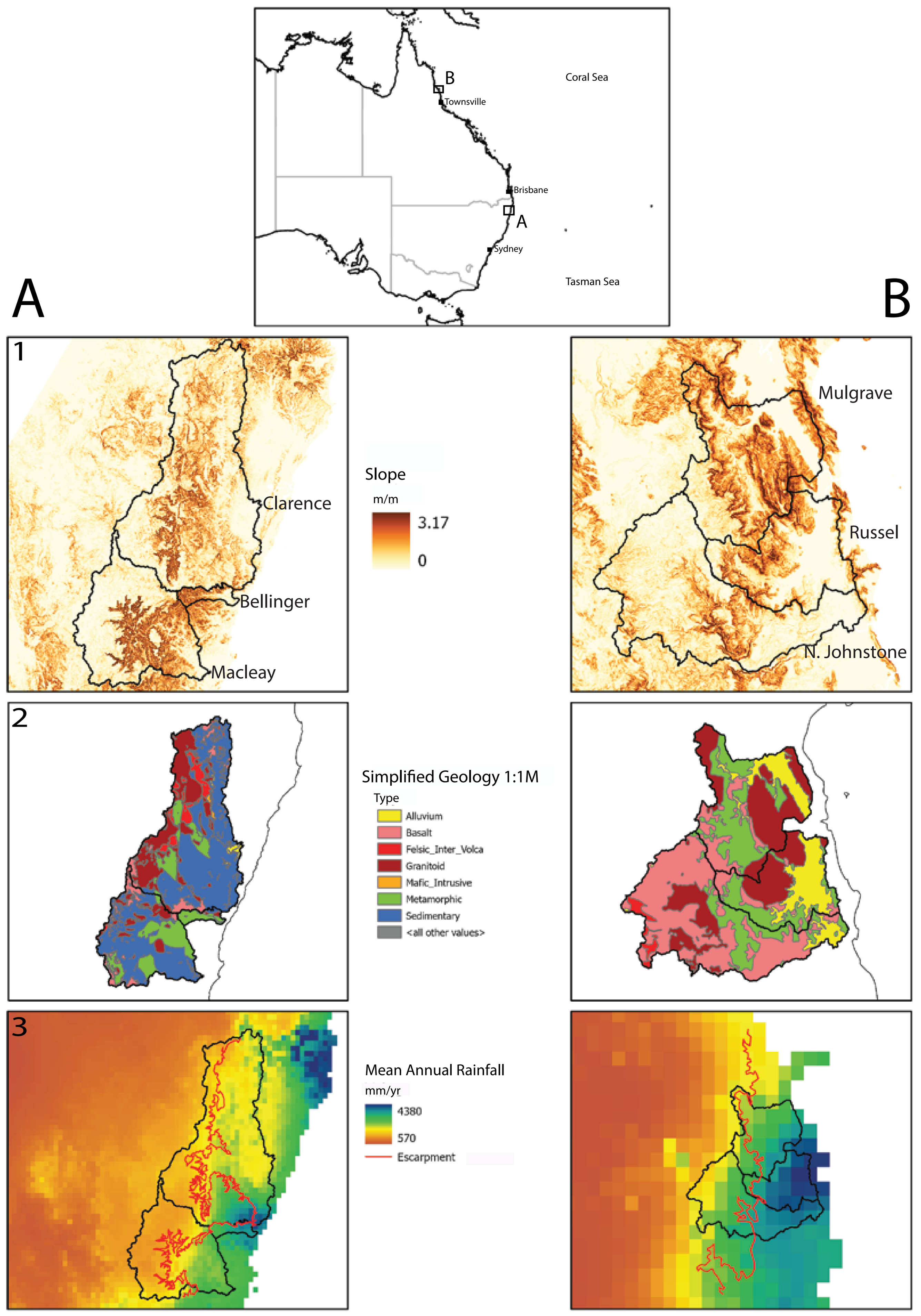

Figure 1 shows the location of the two regions from this study. Box A and corresponding column is the New England region of New South Wales (NSW) and Box/column B is the Bellenden Ker region of Queensland (QLD). All raster data were generated from the 30m resolution SRTM dataset, using the hydrologically enforced DEM-H elevation model gathered from the Australian national database.

Box 1 shows the calculated slope (m/m) for each pixel using a 3x3 moving window on the regional DEMs then cut for each basin to prevent edge effects in calculated values.The dark brown pixels starkly highlight the location of the escarpment as it divides the low topography of the highland plateau (left portion of the plot) from the more low to medium topography of the coastal plain.

Box 2 is a simplified geological map cut from each major river basin using the 1:1,000,000 scale national dataset[1]. Categories were selected based on the primary lithology listed in the metadata, with cases of ambiguity using the secondary lithology description (if present), full description, formation name key words, or the original 1:250,000 maps from Geoscience Australia to confirm descriptions. Metamporphic rocks in both regions are generally lower greenshschist facies of mudstones and siltstones deposited from the Ordovician to Carboniferous[5]. Sedimentary rocks are dominated by arenites and lith-arenites along with conglomerates and diamictites. Granitoids were emplaced during long lasting subduction from Permian to early Cretaceous.

Box 3 shows the mean rainfall calculated from the 5km resolution BOM dataset spanning the years 1911-2000. Overall, there is an aprroximately 3 fold difference between the mean rainfall in the temperate NSW basins (column A) and the tropical QLD basins (column B). The orographic affect due to the escarpment represented by the transition from green/yellow pixels to orange/red in each map along with the ~2-fold increase due to the Bellenden Ker range (column B, dark blue pixels) can clearly be seen.

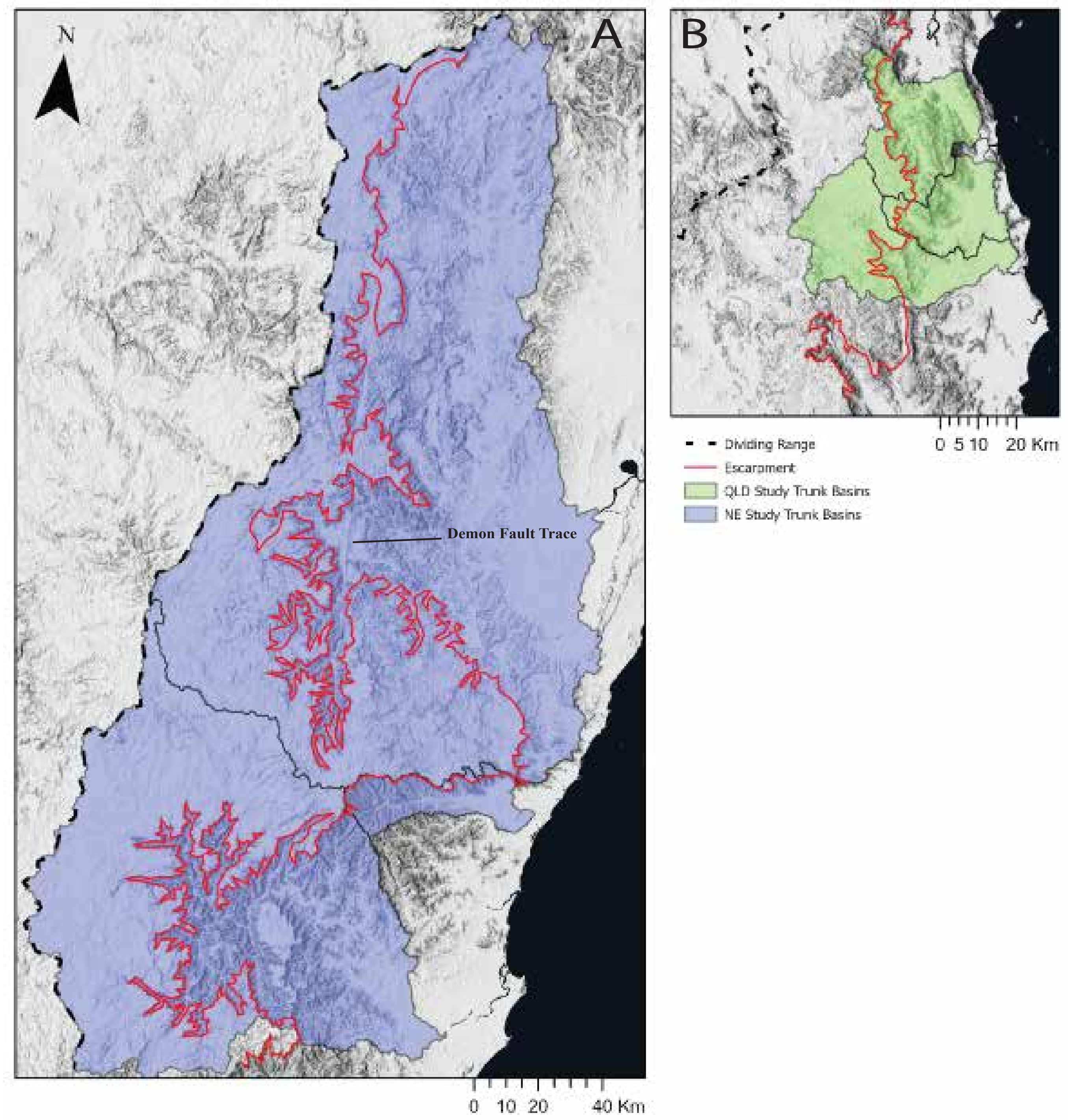

Figure 2 shows the traced lip of the escarpment for each of the study region (thin solid red line) as well as the location of the Great Divide (thick dashed line). The degree of embayment for the NSW (A), with many gorges cut into the plateau vs the more linear QLD escarpment can be visually seen but quantification of the degree is important for absolute comparisons between the two regions. In NSW, (A) escarpment sinuosity was slightly more than double the QLD sinuosity, with calculated values of .14 and .35, respectively. The demon fault trace on the Clarence river (northern basin, A) can be seen and the general N-S direction of the escarpment gorges.Values were calculated from a manually traced line at the 1:500,000 scale for each region and reflect the ratio of straight line distance over actual distance, as such, the lower the number the more sinuous the feature.

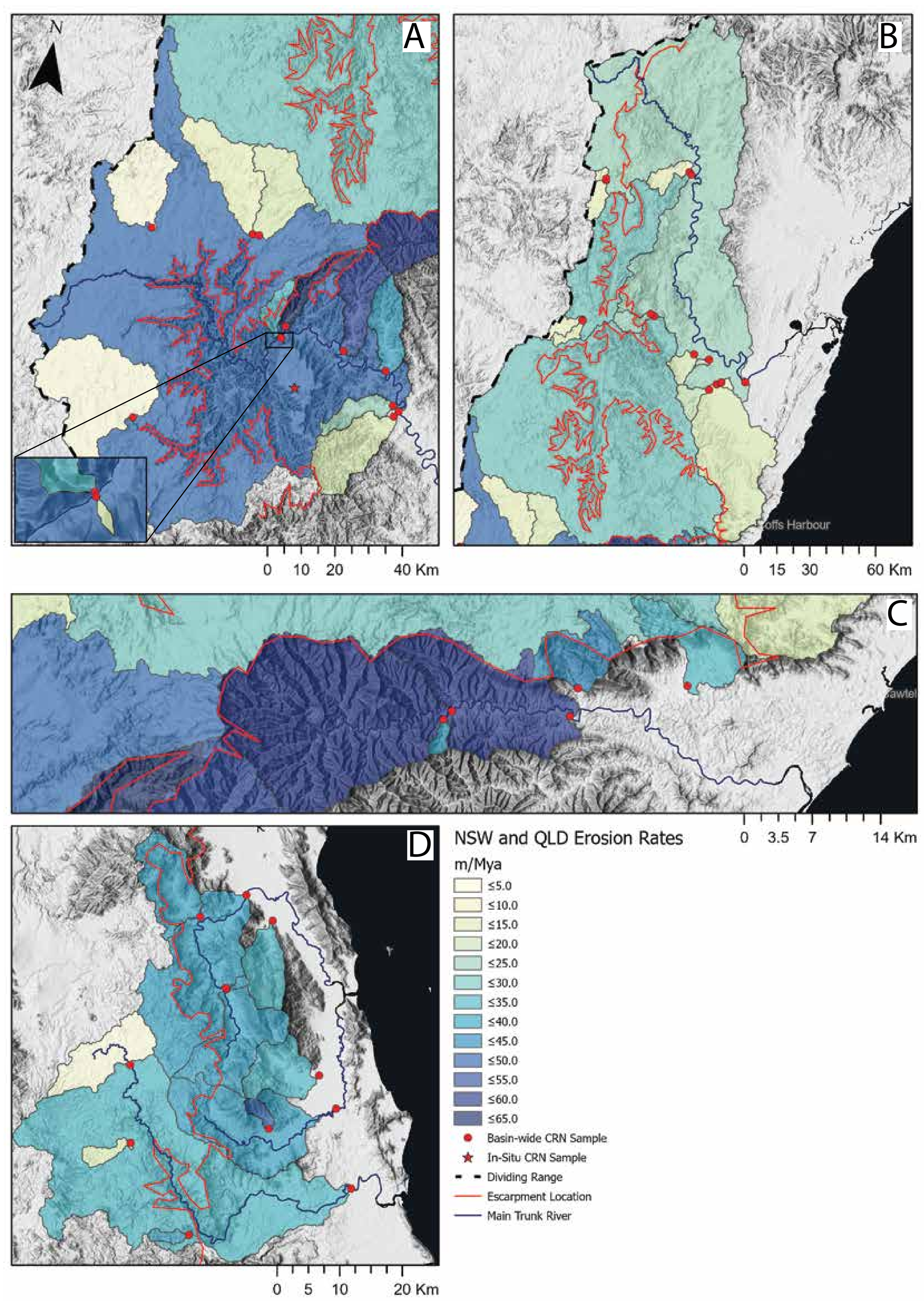

Figure 4 shows the variability of erosion rates across all of the study area's main basins: the Macleay, Clarence and Bellinger of NSW (A, B,C) and the Mulgrave, Russel and North Johnstone of QLD (D). CRN sample locations are denoted with a red circle, and in-situ CRN on the Carrai Plateau (red star). As expected from the data set from NSW, which had such a strong positive linear correlation with slope (figure 3C), erosion rates were maximum from drainages that captured part of the escarpment where mean slopes were maximum (A, B, and C). Coastal plain samples had a smaller degree of variability that depended greatly on the topography of the basin, and upland samples draining the plateau were nearly all below 10m/Mya. Overall, the Clarence river (B) had significantly less variability than the Macleay river, with the highest rates once again along basins draining the escarpment. QLD erosion rates (D) along the escarpment and coastal plain had little variance, regardless of topographic position. The single exception was a sample collected at the base of Josephine Falls on Mt. Bartle Frere where bedrock was exposed just above the collection site and the erosion rate was the highest collected from this area. Escarpment sinuosity from each basin roughly tied with variability of erosion rates, in that the most significant variability was from basins within the Macleay river. The Clarence river, on the other hand, had significant embayment but much less variability in erosion rates. This might be due to the escarpment following the trace of the Demon fault, which can be seen in the roughly N-S linear trend of the gorges.

Basin Characteristic Correlations

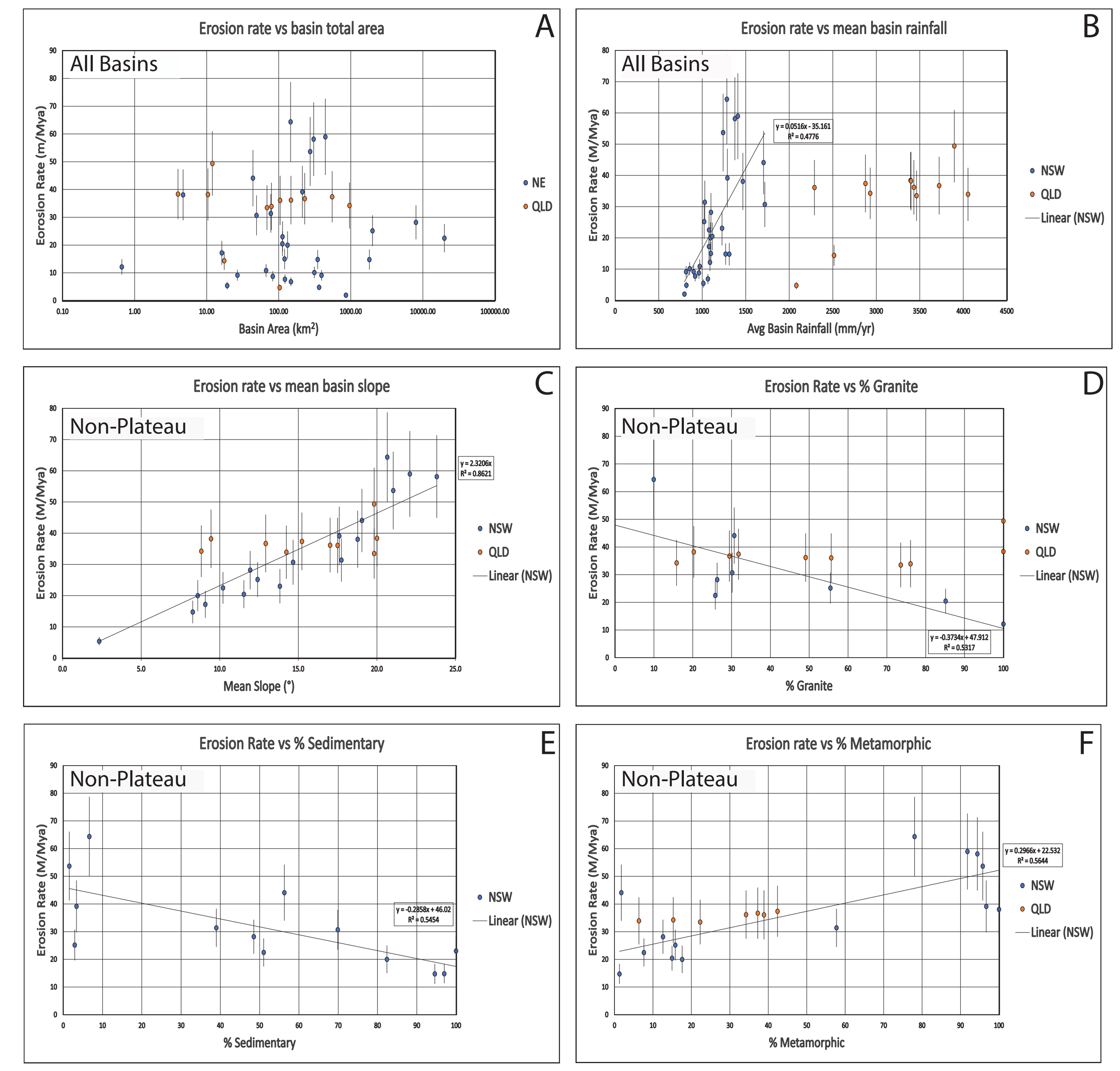

Figure 3 shows the basic metrics calculated for this study vs the basin averaged erosion rate. Basin total area and mean basin rainfall (A and B) both show the complete data set, with the subsequent four plots breaking out the complete data set to only consider the basins draining the escarpment and/or coastal plain as plateau erosion rates were nearly all less than 10m/Ma and independent of all other metrics. As has been found in previous studies along the Australian east coast, no correlation exists between basin total area and its erosion rate (A)[1,2,3]. The weak positive correlation between basin mean rainfall and erosion rate shown in plot 2 is likely autocorrelated due to the strong orographic affect the escarpment has on regional rain patterns (Figure 1, A3 and B3). In NSW (blue circles, all plots), there is a strong positive linear correlation between basin mean slope and its erosion rate (C)[4]. In addition, there were moderate linear correlations between various lithologies and its erosion rate, some expected (negative with % granite [D]) and some surprising (negative with % sedimentary [E]and positive with % metamorphic [F]). The sedimentary and metamorphic lithological correlations could possibly be explained by the variation of particularly strongly cemented sandstones and conglomerates, like the hawkesbury sandstone which forms the majority of the great escarpment south of Sydney, and very lightly metamorphosed (lower greenschist facies) mudstones and siltsones often found in the region[5]. In the QLD data set, there are no such similar correlations. Erosion rates did not vary despite a 2 factor increase in rainfall, larger than two- factor increase in slope, and significant lithological variation (orange circles, all plots). Soil depth profiles from the QLD area indicate that there is a strong lithological control on depth to bedrock, with granitic soils from the Bellenden Ker and Bartle Frere granites that make up the majority of the sample sites having depths to bedrock of >4m[6], which could help explain the significantly less variation in erosion rates when compared to the NSW dataset.

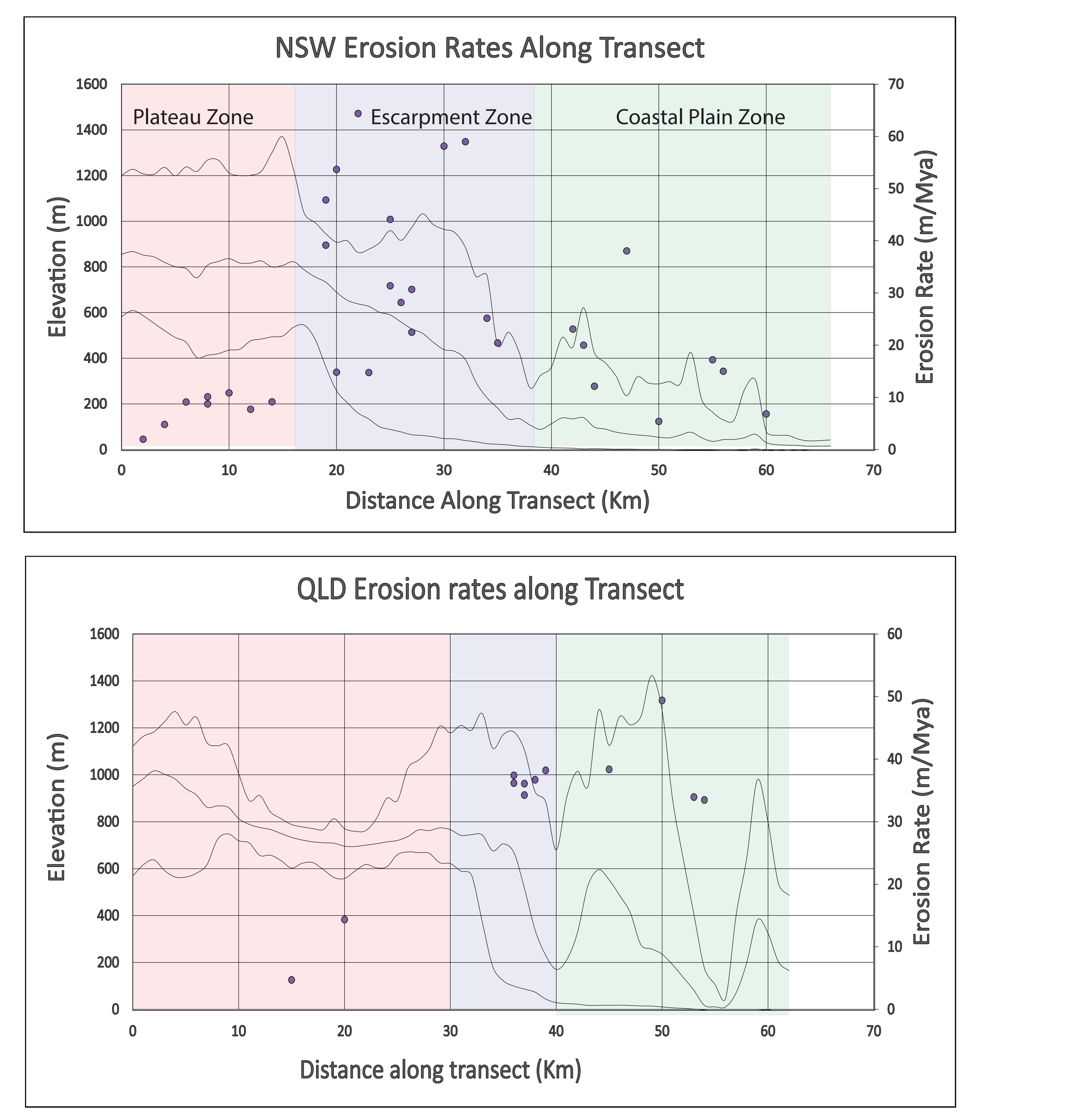

Figure 5 shows the variability of erosion rates by morphologic zone: plateau samples (orange rectangle), escarpment zone (blue rectangle), and coastal plain zone (green rectangle) overlying a representative swath profile of each region. There is considerable variability in the erosion rates of samples draining the escarpment in NSW as expected when erosion rates are strongly tied to slope (figure 3), but significantly less so for the QLD samples. Elevation data was averaged at intervals of 1km over the transect usinga 15km radius buffer. Data was then plotted using the minimum , maximum (thin bounding lines), and mean (middle line) elevation values.

References

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