**SUPPLEMENTARY FILE S-1**

**SYSTEMATIC ANALYSIS OF MIXTURE MODELING RESULTS**

**1. Early Cretaceous (150–110 Ma)**

Deposition of the Early Cretaceous accretionary wedge was contemporaneous with the emplacement of the late stages of the Median Batholith magmatic arc (Adams et al., 2013b, 2016). This relationship is exemplified by the ubiquitous addition of Early Cretaceous detrital zircon age fractions to the Pahau Terrane relative to the older Torlesse Supergroup terranes (Fig. 8). Generally, the Early Cretaceous age fraction appears to be present in much higher abundance (up to 90%) in the northern part of the East Coast basin. The southern portion of the basin has much less Early Cretaceous (<30%) and increased Gondwanan- and Rodinian-affinity age fractions (20–30%; Fig. 8). Based on qualitative comparisons of these age fractions in the Pahau Terrane with older basement terranes, Adams et al. (2013b) interpreted primarily locally-derived Kaweka and Waipapa terranes sources with additional Median Batholith detritus during Barremian through Aptian time. However, by Albian time, Adams et al. (2013b) interpreted a switch to an almost exclusive source of Median Batholith sediment with minor additional Western Province input to the accretionary wedge (locally termed Waioeka Facies).

Mixture modeling results provide a more comprehensive understanding of spatial and temporal variations in relative individual source contributions to the Early Cretaceous accretionary wedge (Fig. 9). In the northern East Coast basin (Raukumara region), the Lower Cretaceous strata of the Pahau Terrane (Barremian–Aptian age) is dominated by a Median Batholith source (~75%) with subordinate local Kaweka Terrane contribution (~15%) (Fig. 9). Conversely, samples from the central East Coast basin (north and south Wairarapa region) have little Western Province terrane contribution (9–23%). Instead, they exhibit primarily Waipapa and Kaweka terrane sources (>50%). In comparison, the southern East Coast basin (Wairarapa through Canterbury regions) has a more diverse array of sediment sources (Fig. 9) that includes significant Median Batholith (5–52%), Buller-Takaka (5–28%), and Brook Street (0–36%) terranes, with additional input (35– 50%) from the Caples and older Torlesse terranes in the North Marlborough segment.

**2. Mid-Cretaceous (110–100 Ma)**

The upper-Lower Cretaceous strata (Albian age) of the Pahau Terrane are dominated by a Median Batholith source contribution across the entirety of the North Island with ~97% contribution in Raukumara and 31–96% throughout the remainder of the basin (Fig. 9). Unlike the older Pahau Terrane, mixture models indicate minor (<6%) contribution of Buller-Takaka Terrane source during this later stage. The Wairarapa and Wellington regions locally have Murihiku and Kaweka terrane components (Fig. 9). No data were available for age-equivalent Pahau Terrane on the South Island.

The Cretaceous section of the Marlborough region exposes some of the oldest cover strata of the Zealandia Megasequence (108–100 Ma; Adams et al., 2013). These were deposited synchronously with the final stages of the Pahau Terrane accretion during the cessation of Cretaceous subduction zone (Adams et al., 2013b; Crampton et al., 2019). Sedimentologic and stratigraphic evidence in the Marlborough region indicates that Late Cretaceous basin strata were locally sourced from structurally uplifted basement blocks (Field and Uruski et al., 1997; Crampton et al., 2019). Heavy mineral analysis further supports a primary Torlesse Supergroup source (Smale and Laird, 1995). However, these rocks have nearly twice the abundance of Early Cretaceous age zircon relative to the Pahau Terrane of the South Island (~40% vs. 20%) (Figs. 5 and 8). These proportions are too high to have been derived from the underlying accretionary rocks. Mixture modeling results instead suggest that a significant secondary source of Lower Cretaceous zircon was derived from the Median Batholith (up to 46%) in addition to the sediment locally recycled Pahau Terrane (34–68%) sediment (Fig. 9).

**3. Mid–Late Cretaceous (100–66 Ma)**

In the northern East Coast basin (Raukumara through Cape Campbell segments), post-100 Ma Cretaceous strata are characterized by a near absence (< 4%) of Early Cretaceous (145–100 Ma) zircon (Fig. 8). Instead, they contain elevated Permian–Triassic (299–201 Ma) and Lower Neoproterozoic–Silurian (720–419 Ma) age fractions. One exception is a sample reported by Adams et al. (2013b) that was collected immediately above an unconformity with the Pahau Terrane and yielded a high (86%) proportion of Early Cretaceous zircon. Mixture modeling of the sample (ECAP8; 51 grains) indicate that it was almost entirely recycled from the underlying basement (Fig. 9). In the case of Upper Cretaceous strata in the northern Raukumara, southern Hawke Bay, and southern Wairarapa segments, mixture modeling results indicate the highest relative contributions of Brook Street Terrane (31–26%) and Buller-Takaka terranes (8–34%) modeled for the entire East Coast basin (Fig. 9). Based upon modeling results, the Kaweka and Rakaia terranes contributed the majority of sediment (34–88% total) to most other regions of the northern East Coast basin. Similarly, the post-100 Ma rocks of the Marlborough (WARD1) and northern Canterbury regions (OKUX1 and CGBN1) were almost entirely sourced from a mixture of Caples, Rakaia, and Kaweka sources (68–74% total), while Western Province sources are nearly absent (Fig. 9).

**4. Paleogene (66–23 Ma)**

The Paleogene stratigraphy of Zealandia is dominated by widespread shallow marine to and deep-water carbonate rocks that were deposited during an extended phase of passive margin tectonics (Field and Uruski et al., 1997). There are few occurrences of Paleogene siliciclastic rocks throughout Zealandia (e.g., Strogen et al., 2014), and these are limited to glauconitic sandstone and calcareous siltstone in the East Coast basin samples. The Paleogene samples from the northern East Coast basin generally match the detrital zircon U-Pb age data from Upper Cretaceous strata (compare Figs. 6 and 7). In North Hawke Bay, Paleocene–Eocene age strata (sample MP33) are completely devoid of Early Cretaceous zircon, whereas the overlying Eocene–Oligocene strata (sample MP31) contains 8%. Similarly, in the North Canterbury segment, detritus within an Eocene age glauconitic-rich sandstone has very minor Cretaceous age fractions (1%). Instead, this stratigraphy is dominated by Permian–Triassic age fractions, with subordinate proportions of Silurian–Devonian zircon (Fig. 8). Mixture modeling indicates that sediment delivered to the Paleogene northern East Coast basin was dominated by a Kaweka Terrane source, but received additional sediment from the Buller-Takaka and Brook Street terranes (Fig. 9). In comparison, the southernmost East Coast basin (North Canterbury) was sourced from Caples and Torlesse terranes (Fig. 9).

Paleogene strata in the Cape Campbell (Eocene glauconitic sandstone) and South Marlborough (late Oligocene calcareous sandstone) areas contrast starkly to this regional trend by containing highly elevated proportions of Early Cretaceous detrital zircon (19–32%) relative to the underlying South Island Pahau Terrane and Cretaceous cover strata (Fig. 8). In addition, Oligocene samples of South Marlborough yielded the first, albeit minor, occurrence of contemporaneous upper Paleogene zircon (ca. 28–24 Ma; 1–2%). Mixture modeling suggests that the Paleogene sediment of the Marlborough region was sourced from a primary combination of Median Batholith (29–53%) and Pahau Terrane (23–41%) sources (Fig. 9).

## 5. Early Miocene (23–16 Ma)

Significant changes in U-Pb age distributions occurred between the deposition of Paleogene to Early Neogene strata: (1) An abrupt loss of significant Early Cretaceous age fraction in the Marlborough region (0–9%) and a slight increase in the northern regions, particularly in the Gisborne segment (20%); (2) an increase in Early and mid–Late Jurassic zircon age fractions (mean of 11%) across the entirety of the East Coast basin; and (3) a minor introduction of Neogene-age zircon to the Gisborne segment of the Raukumara region (Figs. 7, 8).

Overall, the composition of detrital zircon age distributions is similar for Early Miocene strata across the East Coast basin (Fig. 8). However, mixture modeling reveals some regional trends in relative source contributions (Fig. 9). While the Kaweka Terrane provided the greatest proportion of detrital zircon (10–46%) throughout the central and northern East Coast basin, there is a northward increase in Murihiku and Waipapa terrane sources (up to 37% total in Raukumara). Similarly, a southward increase of detrital zircon attributable to Caples and Rakaia terrane sources is resolved (up to 33% in northern Marlborough) (Fig. 9). In the southern Marlborough and Canterbury regions, an abrupt influx of Murihiku Terrane-derived zircon occurs (37–69%) with subordinate Rakaia and Pahau terrane (21–40% total) contributions also noted (Fig. 9).

## 6. Middle Miocene (16–11.6 Ma)

Neogene zircon is present in higher abundances (up to 6%) in middle Miocene strata of the Raukumara region than previously found throughout the northern East Coast basin (Figs. 7, 8). The South Raukumara and Gisborne segments have relatively increased Early Cretaceous (3–18%, mean 13%) and total Jurassic age fractions (mean 19%) (Fig. 8). Middle Miocene strata from these sections are modeled to have been sourced from prominently Murihiku Terrane (12–58%) with subordinate Waipapa and Median Batholith contributions. Samples from the South Raukumara segment received up to 47% contribution from the Pahau Terrane. In the Wairarapa region, Early Cretaceous detrital zircon remained insignificant (1.9%) and subordinate to the proportion of Lower Jurassic (11.7%) grains. The Wairarapa segment is modeled to have been almost entirely sourced from the Kaweka Terrane (80%).

Middle Miocene strata of the Cape Campbell segment of the South Island (LP5) and a sample from North Marlborough (AW32) show an increase in the proportions of Gondwana- and Rodinia-derived detrital zircon. This trend is amplified throughout the East Coast basin during late Miocene time (Fig. 8). More notably, the Cape Campbell and Marlborough regions demonstrate the most striking change in detrital zircon age distributions relative to the lower Miocene age trends. Sandstone-dominated units in these regions (LP5, AW29, and DM15; Fig. 8) all exhibit significant Late Cretaceous age fractions (mean 15%) as a result of contributions from the Pahau Terrane and Median Batholith sediment sources (24–66% and 20%, respectively) (Fig. 9). Independent support for a Pahau source is supplied by middle Miocene conglomerate units that are dominated by locally-derived clasts from the Pahau Terrane and nearby Cretaceous–Paleogene strata. Surprisingly however, a sandstone bed sampled from a conglomerate dominated interval (AW58) yielded only trace Cretaceous (<1%) or Jurassic (0%) detrital zircon, but instead produced the highest proportion of Permian–Triassic age fractions (62%; Table 1) of all Cenozoic samples in the East Coast basin (Figs. 6, 8). This sample is modeled to have been predominantly derived from pre-Cretaceous Eastern Province sources (Fig. 9). The southernmost middle Miocene strata in the North Canterbury segment yielded no Early Cretaceous and fewer Jurassic (10%) detrital zircons than did underlying Paleogene–lower Miocene strata (Figs. 6, 8). Mixture modeling indicates that sediment was sourced from the Murihiku, Caples, and Rakaia terranes.

## 7. Late Miocene (11.6–5.3 Ma)

The detrital zircon age distributions yielded by Upper Miocene strata are highly variable throughout the East Coast basin. Neogene age fractions are present within the North Raukumara to North Wairarapa segments, but are not present in the southern East Coast basin. The proportion of Jurassic detrital zircon is highest in the Raukumara and North Hawke Bay segments (11–25%), while Early Cretaceous age fractions are highest in the Raukumara, Wairarapa to Wellington, and South Marlborough to Canterbury segments (8–17%). Only trace amounts of Early Cretaceous zircon (0–1.7%) occur in South Hawke Bay and North Marlborough. Instead, these latter regions are dominated by Permian–Triassic age fractions (Figs. 7, 8) and also have a high proportion of Gondwana and Rodinia assembly zircon (Fig. 8). Mesoproterozoic zircon (12–15%) is three times more abundant in the Late Miocene South Hawke Bay and North Marlborough segments than it is in the underlying strata in these domains. The same applies to any Eastern Province source terrane (Fig. 3). Sandstone-dominated facies in the South Marlborough and North Canterbury regions are characterized by Late Cretaceous age fractions (mean 16%) with moderate Jurassic age detrital zircon (0–11%).

Mixture modelling indicates that the Kaweka Terrane (up to 74%; mean 37%) was the most common source of sediment across the central to northern East Coast basin. This trend is locally disrupted by the appearance of more distant and local sources along the margin (Fig. 9). For example, the Murihiku Terrane contributed up to 55% of the sediment to the North Hawke Bay and Raukumara regions. The lone exception (TK12) is indicated to primarily have a Pahau Terran source (54%). From North Hawke Bay to North Marlborough, the Caples and Rakaia terranes contribute up to 39%, with the highest proportions being accompanied by significant (26–47%) Western Province (Buller-Takaka and Median Batholith) contributions.

The upper Miocene samples AW27 and WB50 from the North Marlborough segment were acquired from sandstone beds within thick conglomerate units (i.e. Upton Formation) that are locally dominated by Torlesse-derived (likely Pahau Terrane) greywacke clasts. Despite this, the detrital zircon age distributions and modeled sources suggest sediment contributions from older, western terranes. Conversely, there is an abrupt change in sandstone-dominated intervals of the South Marlborough and Canterbury regions to an almost exclusively Pahau Terrane source (70–88%) (Fig. 9).

## 8. Pliocene (5.3–2.6 Ma)

Pliocene strata of the Raukumara and northern Hawke Bay regions exhibit continued occurrence of contemporaneous Neogene zircon (up to 11%) (Figs. 7, 8). For Pliocene samples of the northern East Coast basin, there is an overall decrease in the Early Cretaceous detrital zircon (mean 3%) and concomitant increase in the Early Jurassic age fraction (mean 12%) relative to older Neogene strata (Fig. 8). The relative abundance of Mesoproterozoic zircon is nearly uniform throughout the entirety of the Pliocene East Coast basin (2.5–7.8%, mean 5.7%) and is highest in the South Hawke Bay segment (8%). The Kaweka Terrane is modeled to have been the major source of sediment (64–74%) to the northern East Coast basin (Raukumara–Wairarapa segments) (Fig. 9). The North Hawke Bay segment (sample NU24) provides an exception. There, western-derived Neogene zircon from the Coromandel Volcanic Zone is indicated by mixture modeling to be accompanied by Murihiku and Rakaia terrane sources (23% and 21%, respectively). The Late Miocene dominance of the Kaweka Terrane changes at the latitude of the Wellington segment (PA86; Fig. 9). In this segment, input from the local Torlesse Supergroup terranes is a less significant source of sediment (24% total) with multiple western sources (Buller-Takaka through Caples) combining to make up the difference.

Sandstone-dominated units from the North Marlborough segment have few Jurassic detrital zircon (<5%) and some of the highest proportions of Early Cretaceous age fractions in any Neogene strata (mean 22%). Few Pliocene exposures are present throughout the South Marlborough segment (Fig. 4). Nonmarine gravels occur within the Wairau Valley proximal to the trace of the Alpine Fault (WR48) and an isolated coarse-grained sandstone is present along the coast (CL39). Both of these samples have reduced proportions of Early Cretaceous (mean 4%) and Jurassic (mean 6%) detrital zircon (Figs. 8 and 9). Mixture modeling indicates that while the North Marlborough Pliocene strata was sourced by mixture of Pahau Terrane (47–65%) and Median Batholith (17–25%), the units of the Wairau Valley and coastal South Marlborough were derived from the Murihiku (35%) and Kaweka (48%) terranes, respectively.

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