Pliocene isolation of the Kittitas Valley from the Columbia Basin and implications for uplift of the Hog Ranch-Naneum Anticline

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ABSTRACT

The eruption and widespread emplacement of the mid Miocene Columbia River Basalt Group filled paleo-topography in the Columbia River basin, effectively reset much of the landscape and established a uniform baselevel by ~15 Ma. Tectonic and fluvial processes have since reshaped the landscape dramatically. In central Washington state, the north-south trending Hog Ranch-Naneum anticline (HRNA) is a broad, high amplitude structure that bisects the Columbia Basin and forms the drainage divide between the Yakima and Columbia Rivers. The HRNA intersects and is orthogonal to several Yakima fold structures, which have been mainly active since 3-2.5 Ma. To constrain the timing of uplift along the HRNA, we collected terrestrial sandstone samples interbedded and overlying the Columbia River Basalt Group within the Kittitas Valley watershed, located west of the HRNA. We analyzed U-Pb detrital zircon age spectra for these samples and compared them with coeval stratigraphic horizons east of the HRNA, older locally exposed sandstones, and known sediment sources that deliver sediment into the Yakima and Columbia Rivers. Our provenance results identify a distinct change in sediment source into the Kittitas Valley between mid-Miocene and Pliocene time. Sedimentary horizons interbedded in the Grande Ronde member of the Columbia River Basalt Group (16 – 15.6 Ma) include zircon sources that are distally derived from the Idaho-Wyoming thrust belt and exposed in the modern upper Snake River watershed. Several of the distinctive distally sourced zircon populations are absent from locally exposed Cenozoic units and thus are not recycled from older units. Suprabasaltic (post-5 Ma) sedimentary horizons, on the other hand, only contain older zircon age populations that are recycled from Eocene Swauk and Chumstick formations, units that are located within the Kittitas Valley watershed. These results, along with estimates from sampled strata, indicate that the Kittitas Valley was isolated from the Columbia River basin before ~3.7 Ma. Thus, the HRNA became an agent of drainage division by the Pliocene, prior to the onset of major uplift along the nearby Yakima folds.

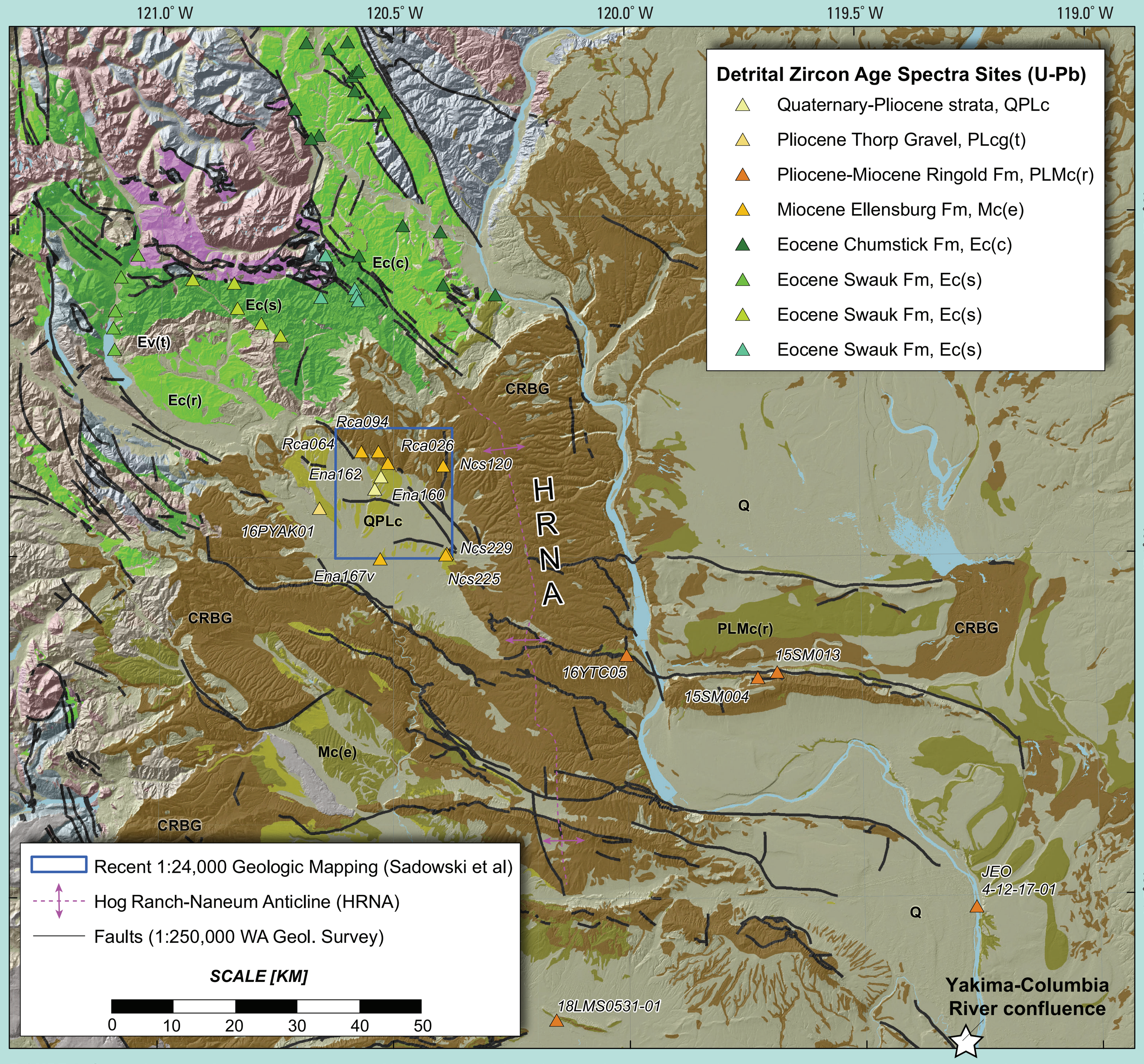

FIGURE 1. Geologic map of central Washington. New and published detrital zircon sample sites are shown in colored triangles with sample numbers labeled. Inset blue rectangle shows extent of detailed mapping, Figure 2.

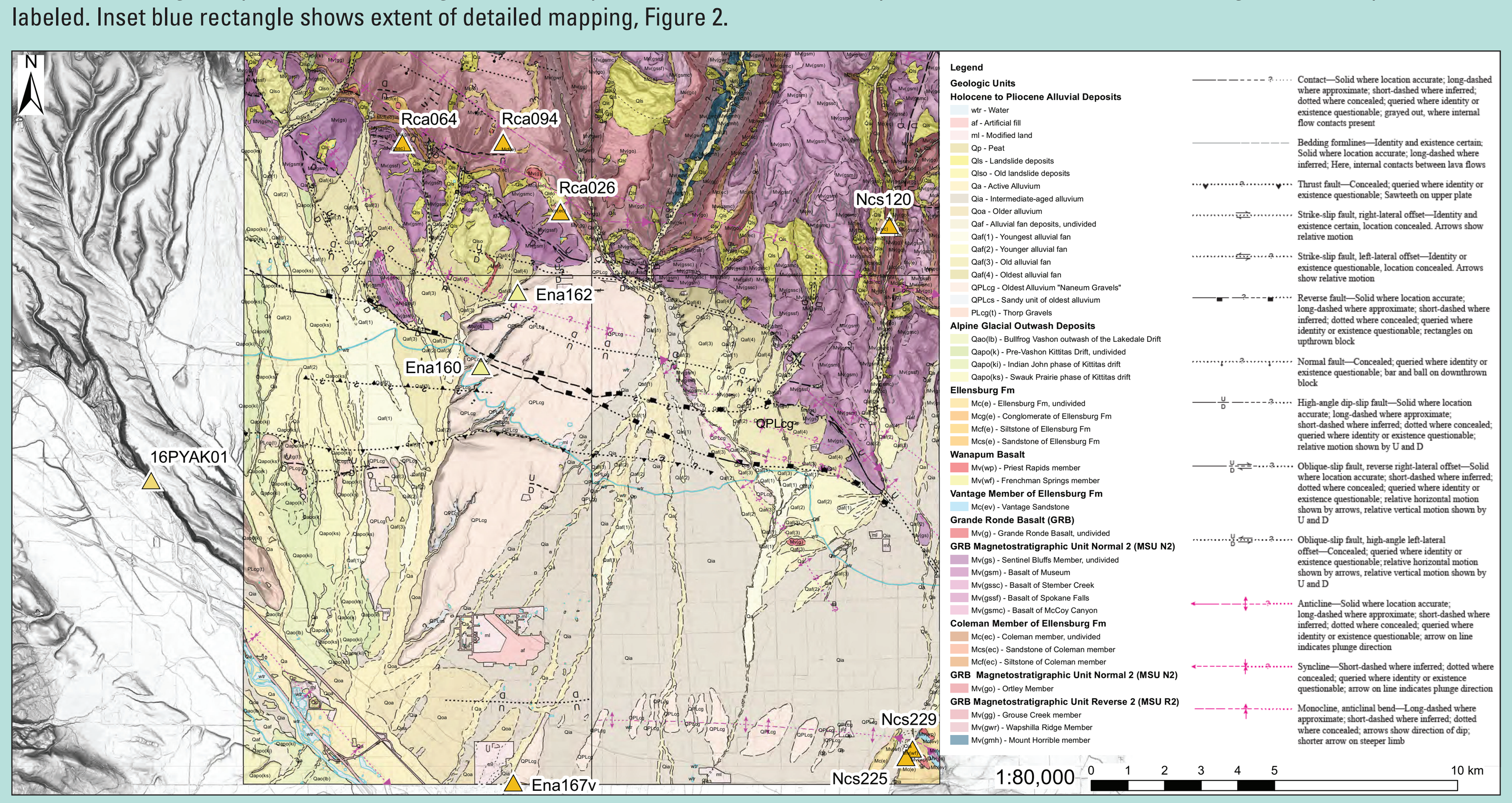

FIGURE 2. Detailed 1:24,000 geologic mapping in northern Kittitas Valley from Sadowski et al. (2010, 2021-in press). Map location denoted as blue box in Figure 1.

GEOLOGIC SETTING

Geomorphology: The Kittitas Valley is located on the east side of the Washington Cascades. The Yakima River flows eastward from the high Cascades and into Kittitas Valley. From there, it decends through Yakima Canyon, where it incises through the active Yakima folds (Bender et al., 2016; Staisch et al., 2018). The modern confluence between the Yakima and Columbia Rivers is located near Richland Washington (Figure 1).

Structural Geology: The Hog Ranch-Naneum anticline (HRNA) is a north-south trending fold that bisects the Yakima and Columbia watersheds (Figure 1). It also bisects the Yakima folds, which are east-west oriented fault cored anticlines that have accommodated an accelerated deformation rate since ~3.0-2.5 Ma (Kelsey et al., 2017; Staisch et al, 2018).

Stratigraphy: Much of the exposed rocks in the Cascadian backarc are basalts of the Columbia River Basalt Group (CRBG), which erupted and flowed over the landscape between ~16-10 Ma. During periods of volcanic quiescence, continental sediments, often fluvial or volcaniclastic in nature, were deposited between basalt flows.

Overlying the CRBG, Miocene-Pliocene strata are exposed in the Kittitas Valley and in the Columbia Basin. The Thorp Gravels and other Pliocene strata in the Kittitas Valley are ~3.7 Ma and younger (Waitt, 1979, Bender et al., 2016). The 9.5-3.0 Ma Ringold formation is deposited in the Columbia Basin, east of the HRNA (Staisch et al., 2017).

DETRITAL ZIRCON DATA AND RESULTS

We collected samples for detrital zircon provenance analysis from continental sediments interbedded within and overlying the CRBG (Figure 3).

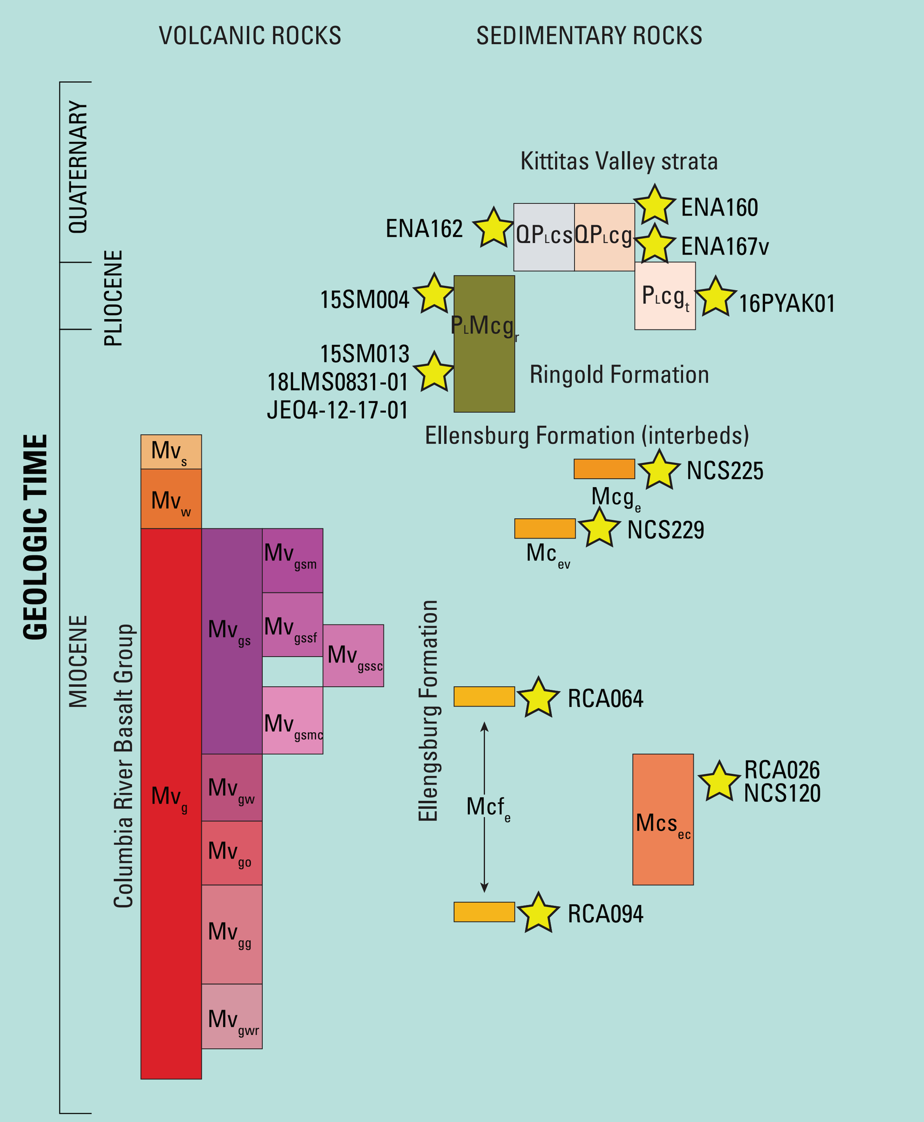

FIGURE 3. Miocene and younger volcanic and sedimentary units exposed in Kittitas Valley and Columbia Basin. Stars represent the stratigraphic horizons sampled for detrital zircon provenance analysis

For each sample, we analyzed 100+ zircon crystals from each sample using Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-PS).

The resulting detrital zircon age spectra from new and previously published samples are plotted in Figure 4. Colored bars correlate to known zircon age population sources from the Pacific Northwest and northern Rocky Mountains.

We compared detrital zircon spectra from samples collected east of the HRNA (Ringold Formation) and west of the HRNA (Ellensburg Formation and suprabasaltic strata) with each other and with potential zircon sources. Sources include:

Locally exposed:

- Eocene Chumstick Formation (Donaghy et al., 2021)
- Eocene Swauk Formation (Gundersen, 2017)

Distally exposed:

- Sources from the upper Snake River drainage (Staisch et al., 2021)
- Sources from central Idaho (Staisch et al., 2021)

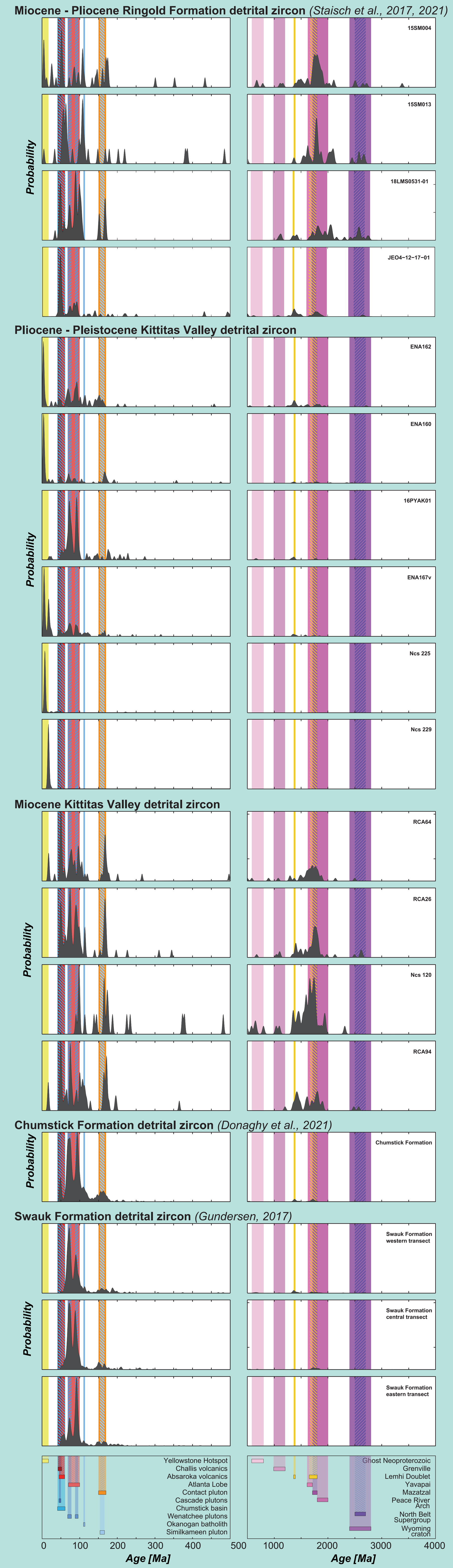

FIGURE 4. Detrital zircon age spectra for newly sampled material from the Kittitas Valley and samples previously analyzed and published from the Ringold Formation, Chumstick Formation, and Swauk Formations. Vertical axes are normalized probability, horizontal axes are time. Note scale change on temporal axes. Detrital zircon spectra are shown in dark grey. Known local and distal zircon sources are shown in colored bars, legend at the bottom correlates color to source.

RESULTS CONTINUED...

Cumulative Density function plots (CDFs) in Figure 5 delineate differences in samples over time and space.

- Miocene-Pliocene Ringold strata collected east of the HRNA show zircon provenance from central Idaho and the upper Snake River, particularly significant abundance of zircons >500 Ma (detailed analysis in Staisch et al., 2021).
- Ringold Formation detrital zircons do not seem to have a strong Yakima River source, noted by the absence of the sharp double age peaks (~65 and ~90 Ma) that are seen in Thorp (16PYAK01), Chumstick, and Swauk samples.
- Miocene Ellensburg strata collected west of the HRNA show similar provenance. Of particular note are ages between 1600 and 1800 Ma and the Eocene Challis/Absaroka volcanic age peaks.
- Suprabasaltic strata (<3.7 Ma) collected west of the HRNA do not have many zircons >500 Ma, and zircon ages match closely with locally exposed Eocene strata (Chumstick and Swauk Formations).

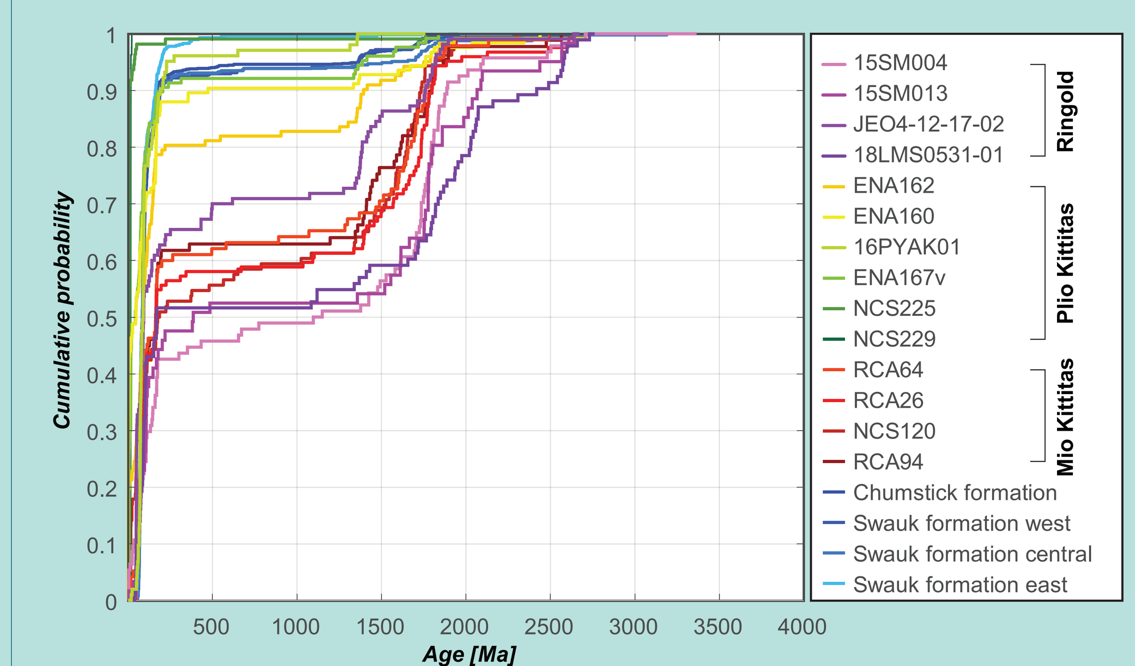

FIGURE 5. Cumulative density function plot of detrital zircon U-Pb age results. Steep vertical steps in the CDF plots indicate abundance of zircon ages of a particular age. Eocene strata locally exposed in the headwaters of Kittitas Valley are in blue shades. Miocene Kittitas Valley strata are in red shades. Pliocene Kittitas strata are in green/yellow shades. Ringold formation strata are shown in purple shades. The overlap in purple and red lines suggests that the mid-Miocene Kittitas strata and Miocene-Pliocene Ringold Formation have similar source terrane. Pliocene Kittitas Valley samples overlap with Eocene Swauk and Chumstick strata, suggesting that zircons from the Eocene units were recycled into the Pliocene Kittitas Valley units.

IMPLICATIONS FOR UPLIFT ALONG THE HRNA

Our new detrital zircon analyses and results suggest that the sediment source into the Kittitas Valley changed significantly between mid Miocene and early Pliocene time.

During the eruption of the CRBG (~16-10 Ma), sediment sourced from central Idaho and the northern Rockies was deposited in the Kittitas Valley (Figure 6A). *These results suggests that there was no topographic barrier between the central Columbia Basin and Kittitas Valley at this time.*

Following CRBG eruption, between ~10 and 3 Ma, sediment sourced from central Idaho and the northern Rockies was deposited in the Columbia Basin, but not from the Kittitas Valley. In the Kittitas Valley, ~3.7 Ma and younger sediments lack zircons indicative of the prior distal source (Fig. 6B). *We interpret this to suggest that tectonic uplift along the HRNA initiated sometime between ~10 and 3.7 Ma.*

Deformation along the Yakima folds, which are orthogonal to the HRNA, accelerated around ~3-2.5 Ma (Staisch et al., 2018). It is unlikely that the east-west trending Yakima folds and north-south trending HRNA were vigorously active at the same time. *We therefore suggest that the majority of deformation along the HRNA was accommodated prior to 3 Ma.*

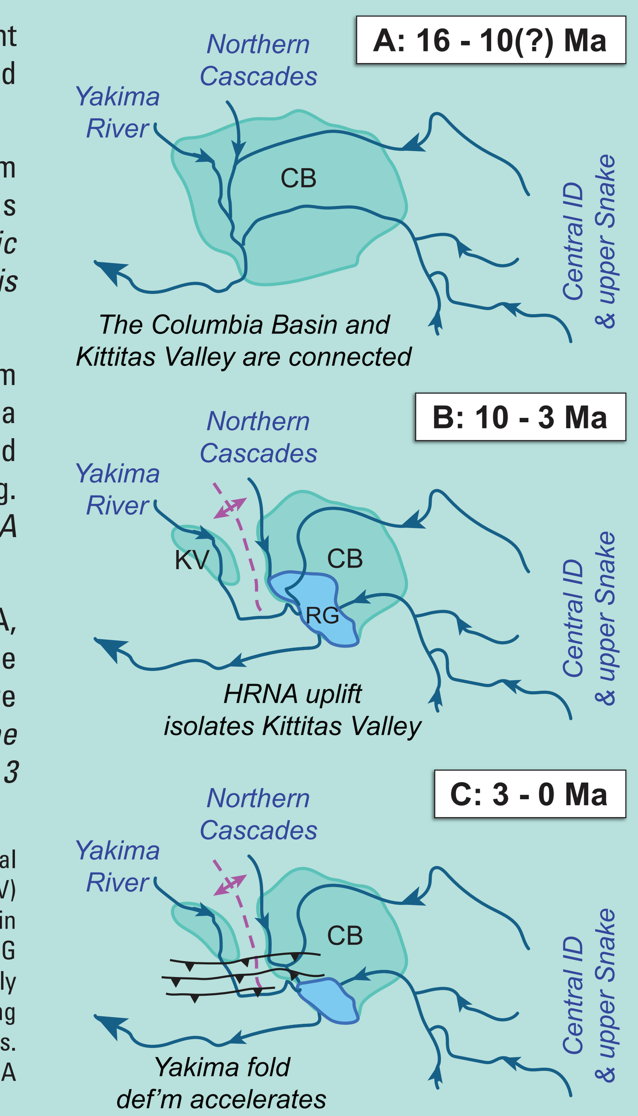

FIGURE 6. Schematic evolution of the depocenters and drainage organization of central Washington. (A) Between 16 and 10 Ma, the Columbia Basin (CB) and Kittitas Valley (KV) were connected. In between periods of CRBG eruption, continental sediments deposited in the modern Kittitas Valley were sourced from local and distal terrane. (B) After major CRBG eruption, the Ringold Formation (RG) was deposited in the Columbia Basin with distally sourced sediment. RG strata lack zircons sourced from the Kittitas drainage, suggesting uplift of the HRNA. Similarly, Pliocene strata in Kittitas Valley lack distally sourced zircons. (C) Tectonic uplift along the Yakima folds accelerates by 3-2.5 Ma, at which point the HRNA is likely tectonically less active or inactive.

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