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Supplemental Material

This document contains five supplementary figures to support the arguments in the main text and aid readers' understanding.

Figure S1 shows the landscape evolution of S0 (orogeny-only) simulation at the end of each episode with an 18-km uplift scale and 60-km elastic thickness, which represents a more moderate scenario of orogenic effect than that in Figure 5. Symbols in Figure S1 are the same as those in Figure 5. Bedrock erodibility is $2*10^{-7}$ yr^{-1} in Figure S1A and $3.5*10^{-7}$ yr^{-1} in Figure S1B. Figure S1A shows that forming a seaway comparable to WIS is even less attainable in this case than that in Figure 5 and that the orogenically-induced sediment mostly fills the foreland so the inland lakes are small and shallow. In this figure, comparison between A and B helps illustrate that with a higher bedrock erodibility (more intense surface processes), the foreland accommodation space is filled more readily (also see Fig. S3) and rivers from the orogen bypass the foreland in the southern WIS. Additionally, Figure S1B represents the S0 reference case (when only flexural deformation is considered) for models considering S1-S3 since the parameters (bedrock erodibility, uplift scale and elastic thickness) are the same among these simulations.

Figure S2 illustrates that the 60-m sea level rise around 100-92 Ma (Haq et al., 1987) has negligible impact on the WIS sedimentation in S0 (pure-orogeny) and S2 (best-fit) simulations. Here, we focus on the million-year-scale sea level change. In landward (eastward) direction, the area of each isopach only slightly expands (<50 km) with sea level rise, suggesting the sea level change should have little impact in both cases. The reason is that the signal of either flexural forebulge (~100 m) or dynamic topography (up to 1000 m) easily overwhelms the signal of sea level change (<60 m) and so dominantly controls the area of sedimentation. Only the first episode (100-94 Ma) is used to examine the effect of sea level change since the sea level becomes rather stable after 92 Ma (Haq et al., 1987). The result further attests that the pre-90 Ma misprediction in S2 should mostly arise from uncertainties in the initial topography and dynamic topography.

Figure S3 offers the basin cross sections with basement topography (black line) and sediment fill (shaded area) in S0 simulations during the third episode (90-84 Ma) at the latitude shown in Figure 5 (and in Fig. S2). This is to support the argument in the main text that sediment supply outpaces the creation of accommodation space and that most of accommodation space is filled. Particularly, the surface of sediment fill can readily reach to or even above the sea level (dashed line) except when flexural rigidity is as large as $10^{25.0}$ Nm. The comparison between two basin profiles with different bedrock erodibilities (B & D) also suggests that higher erodibility leads to a smaller total sediment accumulation in this case. Importantly, the depth of basement at foredeep is smaller in D than in B, implying that here the total sediment accumulation is determined by accommodation space, not sediment supply. Note that higher bedrock erodibility should lead to more sediment supply, but $2*10^{-7}$-yr^{-1} bedrock erodibility results in more sediment accumulation than does $3.5*10^{-7}$-yr^{-1} bedrock erodibility.

Figure S4 shows the S0 sedimentation history in the six episodes with the same bedrock erodibility, uplift scale and elastic thickness as those in Figure S1B and represents the S0 reference case of sedimentation history for S1-S3 (Fig. 9). Note that the amount of sediment in Figure S2 is very little compared to those in Figure 9 because of the lack of additional accommodation space created by dynamic subsidence.

Figure S5 is essentially the same as Figure 10 in the main text, except that the value of uplift scale, instead of bedrock erodibility, is reported with colors. It is demonstrated that there is no clear trend in elastic thickness or uplift scale with any basin features. There is also no preferred universal value for uplift scale or elastic thickness in S1-S3 simulations.

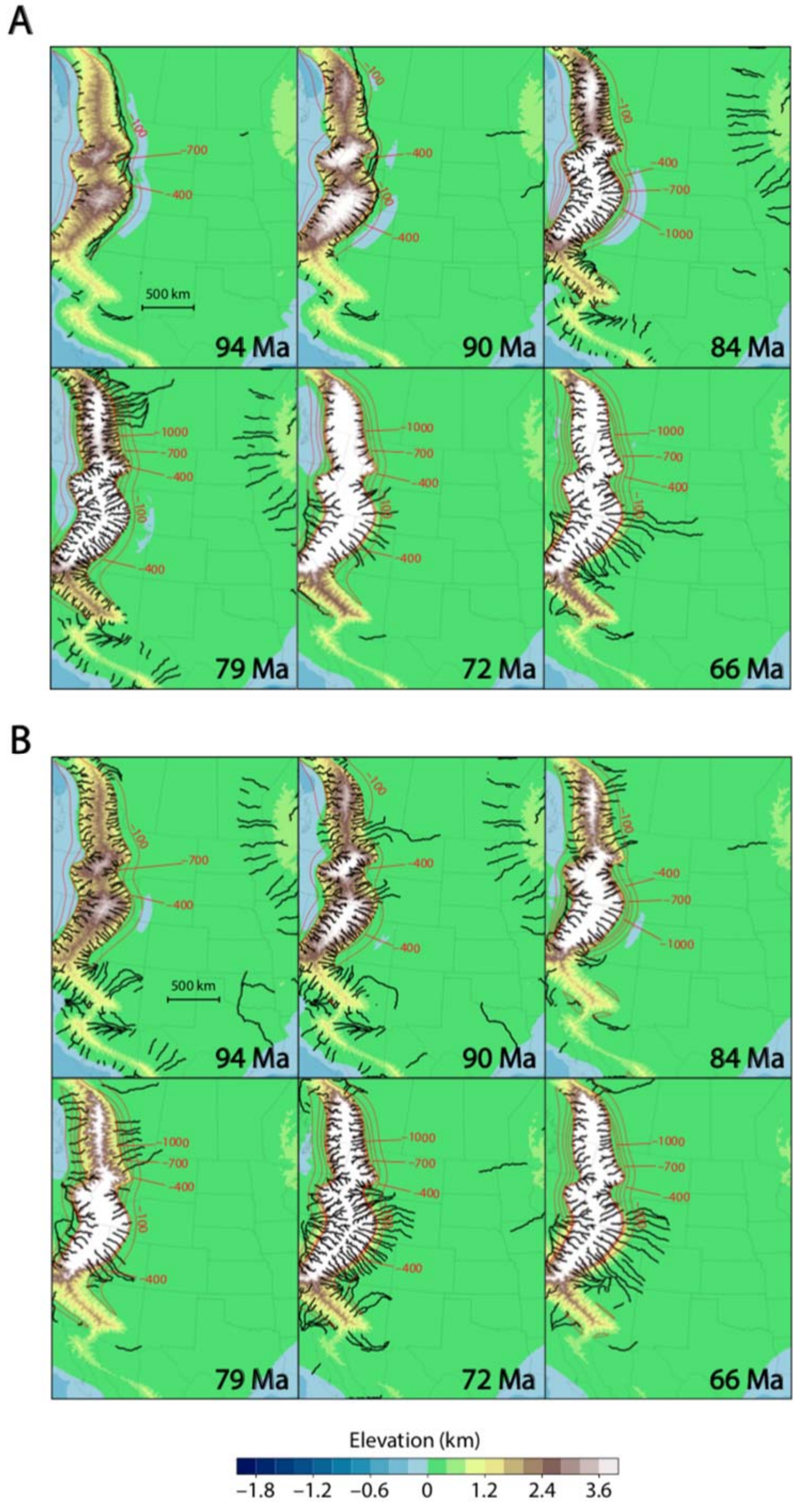

Figure S1. Predicted landscape evolution and rivers in the pure-orogeny tectonic scenario (S0) at the ends of the six uplift episodes (94, 90, 84, 79, 72, and 66 Ma) with the total flexural subsidence in each episode (red contours). Here, bedrock erodibility = $2*10^{-7}$ (A) and $3.5*10^{-7}$ (B), elastic thickness = 60 km, and uplift scale = 18 km. Note that the color interval for submerged area (below sea level) is half of that for subaerial area.

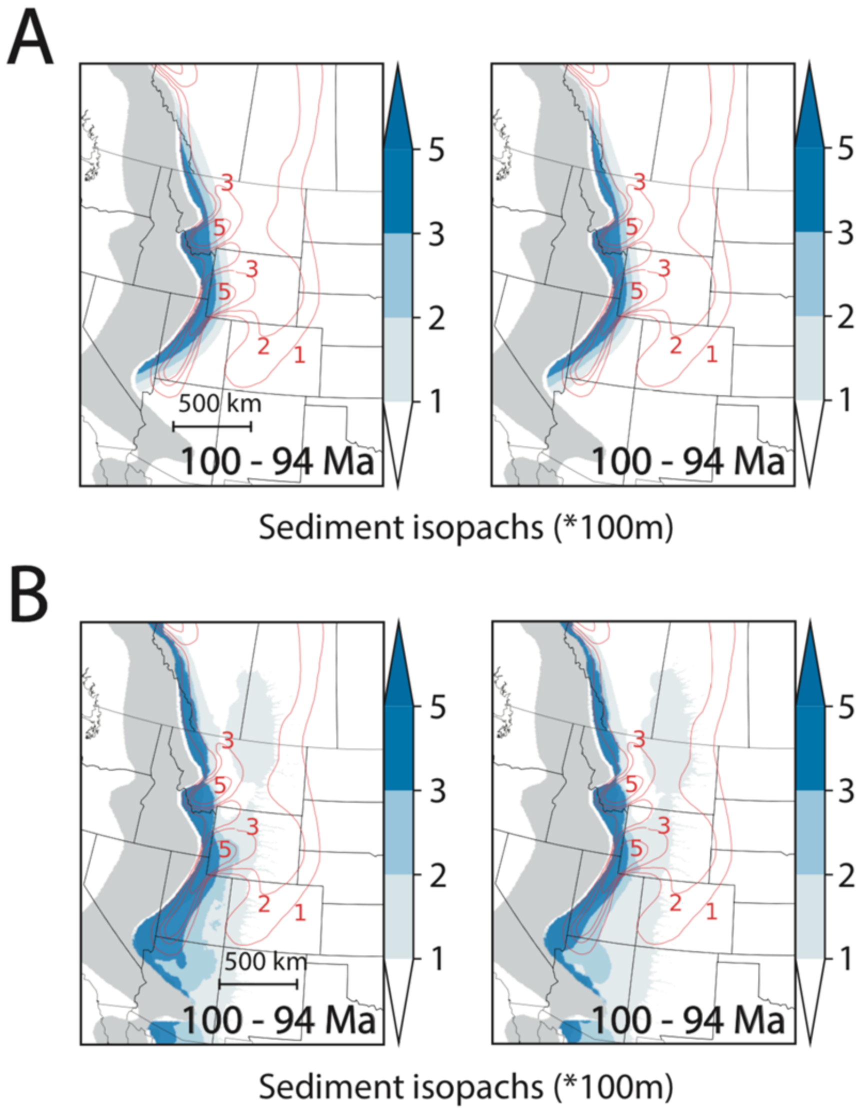

Figure S2. Predicted sedimentation patterns (blue colors) in the first uplift episode compared to those observed (red contours) with (right) and without (left) sea level change from Haq et al. (1987). Here, bedrock erodibility, elastic thickness, and uplift scale are $2*10^{-7}$ yr^{-1}, 120 km, and 21 km in (A), and are $3.5*10^{-7}$ yr^{-1}, 60 km, and 18 km in (B). Another difference is that A) only considers flexural deformation, but B) further considers dynamic topography model S2.

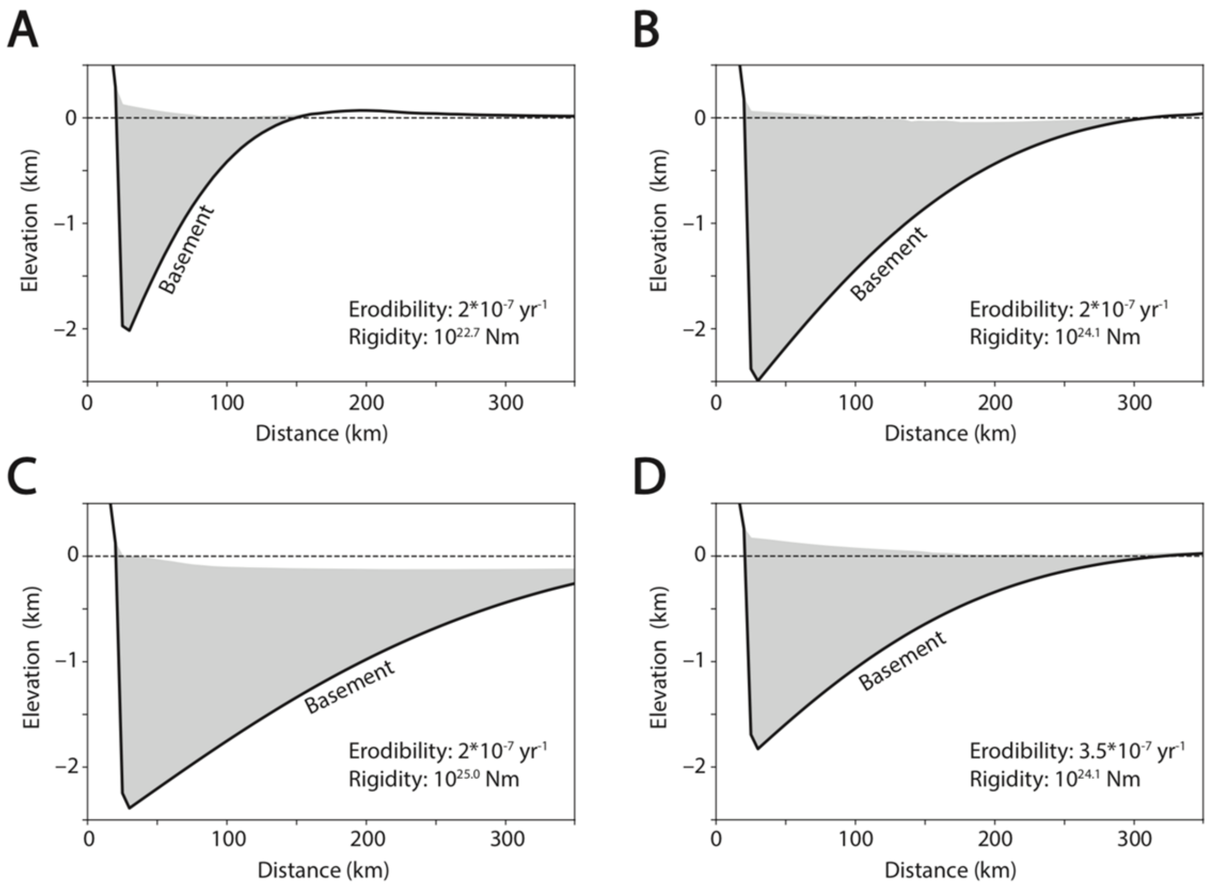

Figure S3. The cross-sectional profiles of the southern WIS basin at the latitude shown in Figure S2 during the third uplift episode (90-84 Ma) with the 100-Ma basement topography (black line) and sediment fill (shaded area). The uplift scale is fixed at 18 km while the values for bedrock erodibility and flexural rigidity are given at the bottom left corner of each panel.

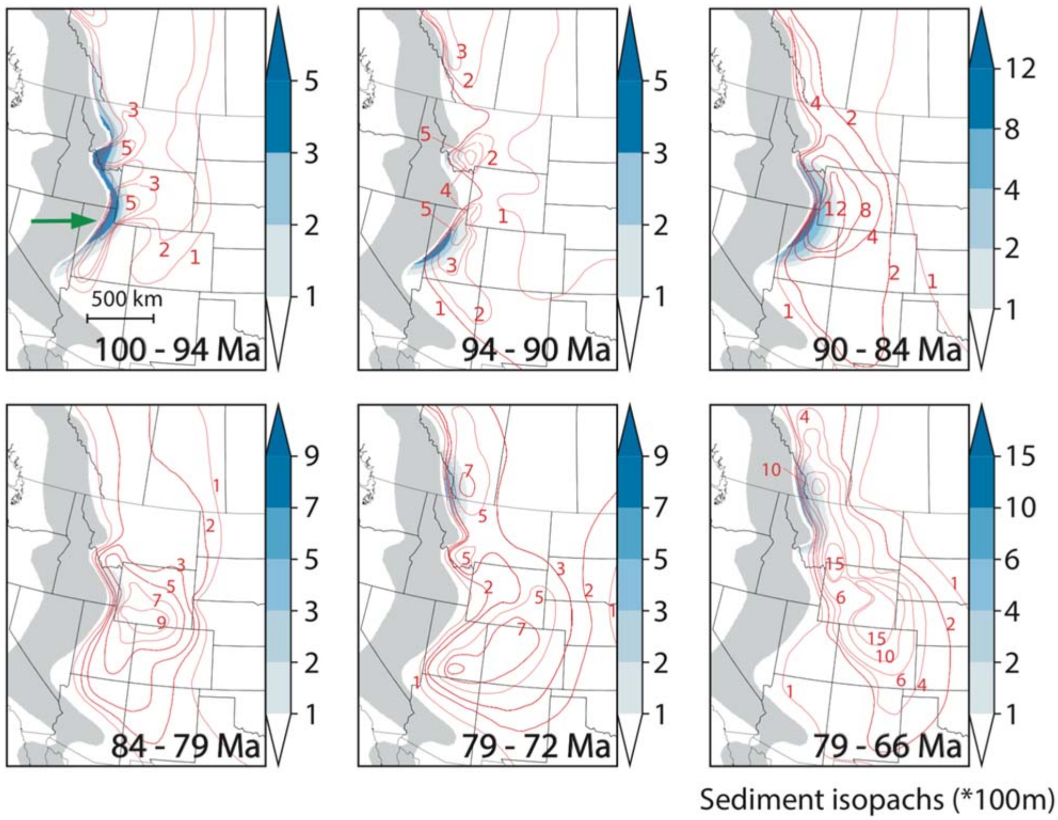

Figure S4. Predicted sedimentation patterns (blue colors) in the six episodes compared to those observed (red contours). Green arrow indicates the latitude at which the uncertainty test evaluates basin features and profiles. Here, bedrock erodibility = $3.5*10^{-7}$, elastic thickness = 60 km, and uplift scale = 18 km.

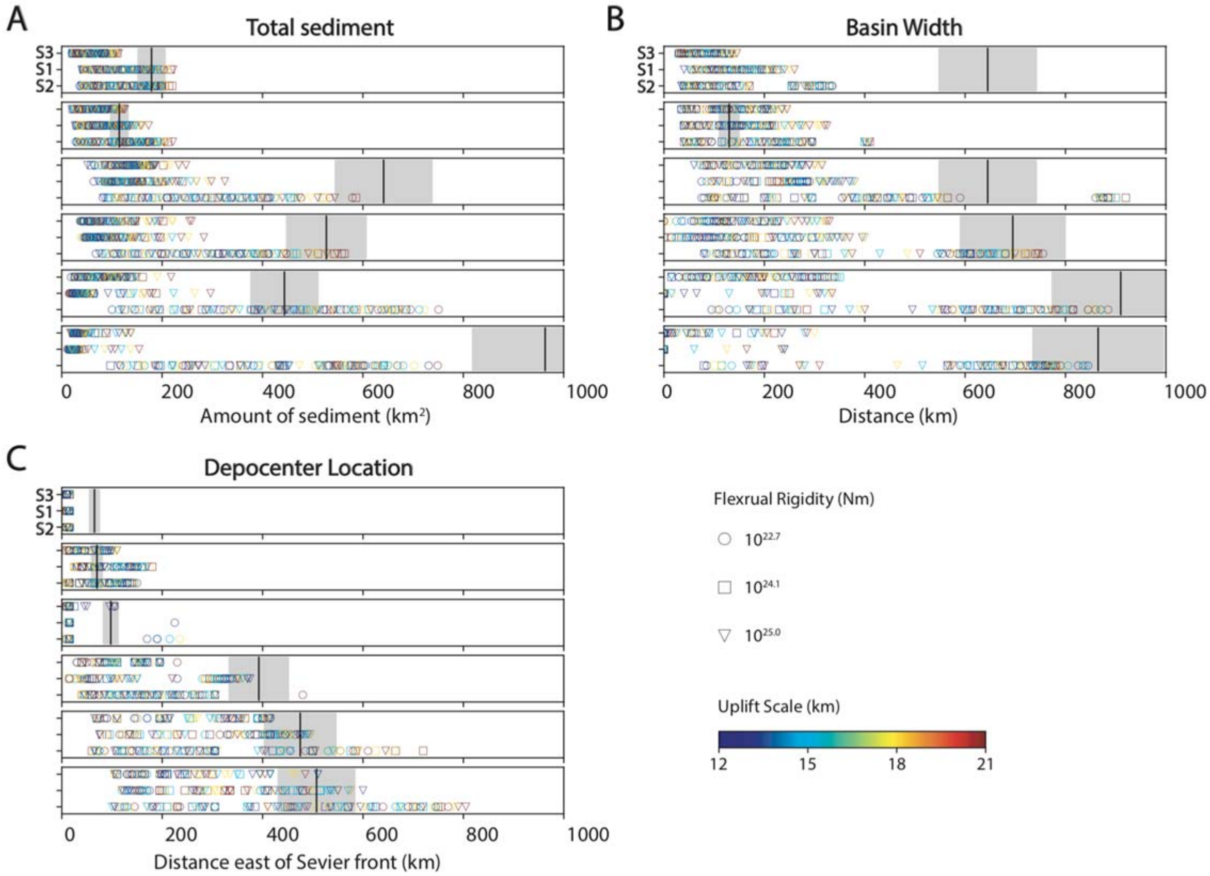

Figure S2. The uncertainty tests on the basin features: total sediment (A), basin width (B), and depocenter location (C). From top to bottom are S3, S1, and S2, respectively, in each episode (one subplot). Vertical lines and grey shades indicate the values derived from the observation with 15% tolerance range. The basin width is defined by the 200 m sedimentary isopach. The lower right section shows the color code for uplift scale and the symbol code for flexural rigidity.