Tectonics

Supporting Information for

Structural Variation of the Southern Hikurangi Subduction Zone, Aotearoa New Zealand, from Seismic Reflection and Retro-Deformation Analysis

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Introduction

In addition to figures that supplement the main text of this publication, the supporting information contained in this document is designed to provide the reader with the critical steps, and detailed description of the method, used to generate our progressive retro-deformation models.

Text S1. In depth description of progressive retro-deformation methodology

The basis of our retro-deformation analysis is to create balanced cross sections from seismic sections in a similar style to Gibbs, (1983), using trishear kinematics (Allmendinger, 1998) to restore strata deformed by fault-propagation folds to lesser states of deformation. We follow a workflow based on that applied in Ghisetti et al., (2016) (for the central Hikurangi margin) to restore our seismic sections.

Through progressive retro-deformation analysis, deformed stratigraphy is sequentially restored to a lesser state of deformation by removal of shortening across individual structures in order of activity from most recent to oldest. Strain may be manifested, for example, by separation of a stratigraphic horizon across a fault, or by folding of a horizon. The interactive structural modelling software MOVE provides several tools for removing such deformation, for example: a simple shear algorithm to remove fault separation without associated folding; a Trishear algorithm for removing slip and folding produced by fault-propagation-folds; and an algorithm for unfolding horizons to an assumed regional datum (e.g., horizontal). The goal of progressive retro-deformation is to determine a kinematically and geometrically feasible deformation pathway that achieves realistic depositional geometries. To examine the development of deformation through time, an age-correlated horizon is 'flattened' to an estimated pre-deformed geometry (i.e., at the point of deposition) and the strain removal to achieve this is applied to the whole stratigraphic succession.

To provide a framework for the sequence of retro-deformation steps applied to each depth-converted transect, we first inferred the fault activity history from analysis of sediment unit thickness variations (see Figure S1; [activity history is described in the main text]).

Most major thrust faults imaged by our profiles show the characteristics of fault-propagation folds: up-dip decreases in fault displacement sometimes terminating in blind fault tips beneath unbreached folds, with onlapping growth strata in the hanging-wall and syn-tectonic thickening of layers in the footwall (Shaw et al., 2005). Where we determine faults to have evidence of fault-propagation-folding, we apply the trishear algorithm and chose values for the parameters that achieve the best fitting removal of the deformation through repeated trial and error. Where faults can be modelled by trishear kinematics the displacement gradient up the fault is a function of the ratio of fault propagation (P) to fault slip (S) (Hughes and Shaw, 2014, 2015). MOVE allows the user to specify trishear parameter values for P/S ratio, displacement and trishear angle for individual faults and to visualise the results interactively.

Where there is no evidence of fault-propagation-folding associated with a fault, the displacement is removed by oblique simple-shear or fault-parallel shear kinematic models (Gibbs, 1983). We repeat this process in the order of the framework defined by our inferred activity history.

For consistency and simplicity, we use the same values for initial porosity and coefficient of change in porosity with depth as Ghisetti et al. (2016) allocated for the sedimentary units bounded by our corresponding reflector sequence (see Figure 2 in the main text). These values, along with the interval velocities, are then used for depth conversion of a subsection of the seismic profiles A-C, where we are more confident in our seismic interpretation. Decompaction of the sedimentary units is also based on these values (Sclater and Christie, 1980), where it is performed as part of progressive retro-deformation of the depth converted transects, for which we also use the method described by Ghisetti et al. (2016) as a guide.

Restored transects, depicting the estimated geological structure at time-steps defined by the ages of the reflectors R0-R5 are achieved through the same progressive, two-step process used by Ghisetti et al. (2016): (1) progressive removal of deformation above the basal décollement from the present-day (deformed seafloor R0) to 'flatten' the horizon representing the most recent stage of deposition during each sequence (R0-R3, R3-R4, R4-R5); and (2) subsequent decompaction and back-stripping of the respective sequence, using the Sclater and Christie (1980) relationship. We do not make any adjustments for sea-level and palaeo-bathymetric changes.

Text S2. Progressive Retro-Deformation Restoration Steps for Profile A (MH44), Figure 7

Values for parameters provided below were achieved through interactive trial and error. The starting model is the structural interpretation for the present day (Figure 7E). Steps indicate process undertaken to model previous states of deformation from Figure 7E to 7A:

Stage 5 (Figure 7E) is present-day condition.

7D.1. Proto thrusts (AMF1) restored using simple shear.

7D.2. Trishear on Fault A1, with separation -300 m; trishear angle 120°; trishear angle offset 0.9; propagation/slip ratio 5; trishear zones 1; angular shear 2°; position of the virtual fault tip for restoration set at the R3 hanging-wall level.

7D.3. Faulting in hanging-wall anticline of Fault A1 (AMF2) restored using simple shear.

7D.4. Trishear on Fault A5, with separation -500 m; trishear angle 100°; trishear angle offset 0.8; propagation/slip ratio 5; trishear zones 1; angular shear 2°; position of the virtual fault tip for restoration set halfway between R4 footwall and hanging-wall levels.

7D.5. Trishear on Fault A6, with separation -350 m; trishear angle 70°; trishear angle offset 0.6; propagation/slip ratio 5; trishear zones 1; angular shear 2°; position of the virtual fault tip for restoration set just above the R5B hanging-wall level.

7D.6. Trishear on Fault A8, with separation -275 m; trishear angle 80°; trishear angle offset 0.5; propagation/slip ratio 3; trishear zones 1; angular shear 2°; position of the virtual fault tip for restoration set just above the R5B hanging-wall level.

Results of above shown by Figure 7D (main text) – Stage 2.

7C.1. Decompaction of the sediment sequence between R0 and R3.
7C.2. Trishear on Fault A1, with separation -1900 m; trishear angle 60°; trishear angle offset 0.75; propagation/slip ratio 5; trishear zones 4; angular shear 2°; position of the virtual fault tip for restoration set halfway between R4 and R5 horizon levels.
7C.3. Trishear on Fault A2, with separation -560 m; trishear angle 60°; trishear angle offset 0.6; propagation/slip ratio 12; trishear zones 5; position of the virtual fault tip for restoration set at the R5 horizon level.
7C.4. Faulting in hanging-wall anticline of Fault A2 (AMF3) restored using simple shear.
7C.5. Trishear on Fault A3, with separation -900 m; trishear angle 50°; trishear angle offset 0.75; propagation/slip ratio 8; trishear zones 4; angular shear 2°; position of the virtual fault tip for restoration set at the R5 horizon level.
7C.6. Faulting in hanging-wall anticline of Fault A3 (AMF4) restored using simple shear.
7C.7. Trishear on Fault A4, with separation -520 m; trishear angle 70°; trishear angle offset 0.5; propagation/slip ratio 3; trishear zones 1; angular shear 2°; position of the virtual fault tip for restoration set at seabed.
7C.8. Most faulting in hanging-wall anticline of Fault A4 (AMF5) restored using simple shear.
7C.9. Simple shear on Fault A4_bt to restore remaining separation across R4 horizon.
7C.10. Trishear on Fault A5, with separation -300 m; trishear angle 60°; trishear angle offset 0.3; propagation/slip ratio 5; trishear zones 2; angular shear 2°; position of the virtual fault tip for restoration set at seabed.
7C.11. Trishear on Fault A6, with separation -300 m; trishear angle 80°; trishear angle offset 0.7; propagation/slip ratio 6; trishear zones 1; angular shear 2°; position of the virtual fault tip for restoration set at R5 hanging-wall level.
7C.12. Trishear on Fault A8, with separation -250; trishear angle 100°; trishear angle offset 0.7; propagation/slip ratio 5; trishear zones 1; angular shear 2°; position of the virtual fault tip for restoration set at the R4 hanging-wall level;
7C.13. Simple shear on Fault A8_bt1 to restore offset of R4 horizon.
7C.14. Simple shear on Fault A8_bt2 to restore offset of R4 horizon.
7C.15. Simple shear on Fault A9 to restore offset of R4 horizon.

Result of above shown by Figure 7C (main text) – Stage 3.

7B.1. Decompaction of the sediment sequence between R3 and R4.
7B.2. Trishear on Fault A4, with separation -1800 m; trishear angle 30°; trishear angle offset 0.4; propagation/slip ratio 4; trishear zones 3; angular shear 2°; position of the virtual fault tip for restoration set at the R5 hanging-wall level.
7B.3. Trishear on Fault A5, with separation -400 m; trishear angle 100°; trishear angle offset 0.7; propagation/slip ratio 1; trishear zones 1; angular shear 2°; position of the virtual fault tip for restoration set at the R5 hanging-wall level.
7B.4. Simple shear on Fault A6_bt to restore offset of R5 horizon.

7B.5. Trishear on Fault A6, with separation -2800 m; trishear angle 50°; trishear angle offset 0.5; propagation/slip ratio 1; trishear zones 3; angular shear 2°; position of the virtual fault tip for restoration set at the seabed.
7B.6. Trishear on Fault A7, with separation -1700 m; trishear angle 50°; trishear angle offset 0.5; propagation/slip ratio 1; trishear zones 1; angular shear 2°; position of the virtual fault tip for restoration set at the R5 hanging-wall level.
7B.7. Trishear on Fault A7_fs, with separation -550 m; trishear angle 50°; trishear angle offset 0.5; propagation/slip ratio 1; trishear zones 1; angular shear 2°; position of the virtual fault tip for restoration set at the seabed.
7B.8. Simple shear on Fault A8_bt1 to restore offset of R5 horizon.
7B.9. Trishear on Fault A8, with separation -1800 m; trishear angle 80°; trishear angle offset 0.9; propagation/slip ratio 2; trishear zones 3; angular shear 2°; position of the virtual fault tip for restoration set at the seabed.
7B.10. Simple shear on Fault A8_bt2 to restore offset of R5 horizon.
7B.11. Trishear on Fault A9, with separation -950 m; trishear angle 80°; trishear angle offset 0.4; propagation/slip ratio 2; trishear zones 1; angular shear 2°; position of the virtual fault tip for restoration set at the seabed.
7B.12. Unfolding of strata between A9 and A8_bt2 guided to flatten R5B horizon.

Result of above shown by Figure 7B (main text) – Stage 2.

7A.1. Decompaction of the sediment sequence between R4 and R5.
7A.2. Trishear on Fault A4, with separation -350 m; trishear angle 50°; trishear angle offset 0.5; propagation/slip ratio 12; trishear zones 3; angular shear 2°; position of the virtual fault tip for restoration set at the R5 hanging-wall level.
7A.3. Trishear on Fault A5, with separation -120 m; trishear angle 50°; trishear angle offset 0.5; propagation/slip ratio 1; trishear zones 1; angular shear 2°; position of the virtual fault tip for restoration set at the R5 hanging-wall level.
7A.4. Trishear on Fault A6, with separation -400 m; trishear angle 120°; trishear angle offset 0.8; propagation/slip ratio 5; trishear zones 3; angular shear 2°; position of the virtual fault tip for restoration set at the R5 hanging-wall level.
7A.5. Trishear on Fault A6_bt, with separation -475 m; trishear angle 70°; trishear angle offset 0.4; propagation/slip ratio 6; trishear zones 3; angular shear -5°; position of the virtual fault tip for restoration set at the R5 level.
7A.6. Trishear on Fault A8, with separation -600 m; trishear angle 50°; trishear angle offset 0.5; propagation/slip ratio 1; trishear zones 1; angular shear 2°; position of the virtual fault tip for restoration set at the R5 hanging-wall level.
7A.7. Additional trishear on fault within Fault A8 hanging-wall, with separation -200 m; trishear angle 120°; trishear angle offset 0.9; propagation/slip ratio 1; trishear zones 1; angular shear 2°; position of the virtual fault tip for restoration set at just above R5B horizon.
7A.8. Simple shear on Fault A8_bt1 to restore offset of R5B horizon.
7A.9. Simple shear on Fault A9 to restore offset of R5B horizon.

Result of above shown by Figure 7A (main text) – Stage 1.

Text S3. Progressive Retro-Deformation Restoration Steps for Profile B (PEG09-017), Figure 8

Values for parameters provided below were achieved through interactive trial and error. Starting model is the structural interpretation for the present day (Figure 8E). Steps indicate process undertaken to model previous states of deformation from Figure 8E to 8A:

Stage 5 (Figure 8E) is present-day condition.

8D.1. Trishear on Fault B1, with separation -65 m; trishear angle 100°; trishear angle offset 0.8; propagation/slip ratio 7; trishear zones 1; no angular shear; position of the virtual fault tip for restoration set at the seabed.

8D.2. Trishear on Fault B4_fs, with separation -150 m; trishear angle 80°; trishear angle offset 0.8; propagation/slip ratio 8; trishear zones 2; angular shear 2°; position of the virtual fault tip for restoration set at just below seabed.

8D.3. Trishear on Fault B4, with separation -100 m; trishear angle 80°; trishear angle offset 0.8; propagation/slip ratio 8; trishear zones 2; angular shear 2°; position of the virtual fault tip for restoration set at the seabed.

8D.4. Trishear on Fault B4_fs backthrust, with separation -25 m; trishear angle 60°; trishear angle offset 0.6; propagation/slip ratio 10; trishear zones 1; angular shear -2°; position of the virtual fault tip for restoration set at the R5 hanging-wall level.

8D.5. Trishear on Fault B4_bt, with separation -150 m; trishear angle 80°; trishear angle offset 0.5; propagation/slip ratio 10; trishear zones 1; angular shear -2°; position of the virtual fault tip for restoration set at the R5 hanging-wall level.

8D.6. Trishear on Fault B6_fs, with separation -100 m; trishear angle 50°; trishear angle offset 0.5; propagation/slip ratio 5; trishear zones 1; angular shear -2°; position of the virtual fault tip for restoration set at the seabed.

8D.7. Trishear on Fault B8_fs, with separation -450 m; trishear angle 70°; trishear angle offset 0.7; propagation/slip ratio 5; trishear zones 1; angular shear 2°; position of the virtual fault tip for restoration set at the seabed.

Result of above shown by Figure 8D (main text) – Stage 4.

8C.1. Decompaction of the sediment sequence between R0 and R3.

8C.2. Trishear on Fault B3_bt, with separation -100 m; trishear angle 50°; trishear angle offset 0.8; propagation/slip ratio 10; trishear zones 1; angular shear -0.5°; position of the virtual fault tip for restoration set at the seabed.

8C.3. Trishear on Fault B4_fs, with separation -100 m; trishear angle 80°; trishear angle offset 0.8; propagation/slip ratio 12; trishear zones 3; no angular shear; position of the virtual fault tip for restoration set at just below seabed.

8C.4. Trishear on Fault B4_fs backthrust, with separation -50 m; trishear angle 80°; trishear angle offset 0.8; propagation/slip ratio 10; trishear zones 1; angular shear -2°; position of the virtual fault tip for restoration set at the seabed.

8C.5. Trishear on Fault B4_bt, with separation -150 m; trishear angle 60°; trishear angle offset 0.3; propagation/slip ratio 12; trishear zones 1; angular shear -2°; position of the virtual fault tip for restoration set at the R5 hanging-wall level.
8C.6. Trishear on Fault B4, with separation -120 m; trishear angle 80°; trishear angle offset 0.9; propagation/slip ratio 12; trishear zones 1; angular shear 1°; position of the virtual fault tip for restoration set at the R5 level.
8C.7. Trishear on Fault B6_fs, with separation -100 m; trishear angle 50°; trishear angle offset 0.5; propagation/slip ratio 1; trishear zones 1; no angular shear; position of the virtual fault tip for restoration set at the seabed.
8C.8. Trishear on Fault B6, with separation -200 m; trishear angle 80°; trishear angle offset 0.7; propagation/slip ratio 5; trishear zones 3; no angular shear; position of the virtual fault tip for restoration set at the seabed.
8C.9. Trishear on Fault B8_fs, with separation -500 m; trishear angle 80°; trishear angle offset 0.8; propagation/slip ratio 3; trishear zones 1; angular shear 2°; position of the virtual fault tip for restoration set at the seabed.
8C.10. Trishear on Fault B7, with separation -500 m; trishear angle 80°; trishear angle offset 0.8; propagation/slip ratio 7; trishear zones 1; angular shear 2°; position of the virtual fault tip for restoration set at the R4 level.
8C.11. Trishear on Fault B8, with separation -200 m; trishear angle 70°; trishear angle offset 0.7; propagation/slip ratio 5; trishear zones 1; no angular shear; position of the virtual fault tip for restoration set at the R4 level.

Result of above shown by Figure 8C (main text) – Stage 3.

8B.1. Decompaction of the sediment sequence between R3 and R4.
8B.2. Trishear on Fault B1_bt, with separation -170 m; trishear angle 70°; trishear angle offset 0.4; propagation/slip ratio 3; trishear zones 1; angular shear -0.5°; position of the virtual fault tip for restoration set at the R5 horizon level.
8B.3. Trishear on Fault B1, with separation -1000 m; trishear angle 80°; trishear angle offset 0.7; propagation/slip ratio 5; trishear zones 1; angular shear 2°; position of the virtual fault tip for restoration set hallway between R4 and R5.
8B.4. Trishear on Fault B2_bt, with separation -300 m; trishear angle 80°; trishear angle offset 0.7; propagation/slip ratio 6; trishear zones 1; angular shear -0.5°; position of the virtual fault tip for restoration set at the R5 horizon level.
8B.5. Trishear on Fault B2, with separation -800 m; trishear angle 50°; trishear angle offset 0.8; propagation/slip ratio 5; trishear zones 1; angular shear 2°; position of the virtual fault tip for restoration set hallway between R4 and R5.
8B.6. Trishear on Fault B3, with separation -600 m; trishear angle 60°; trishear angle offset 0.7; propagation/slip ratio 5; trishear zones 1; angular shear 2°; position of the virtual fault tip for restoration set at the seabed.
8B.7. Simple shear on Fault B3_bt to restore offset of R5 horizon.
8B.8. Trishear on Fault B4_fs, with separation -550 m; trishear angle 50°; trishear angle offset 0.7; propagation/slip ratio 5; trishear zones 1; no angular shear; position of the virtual fault tip for restoration set at the seabed.

8B.9. Simple shear on B4_fs backthrust to restore offset of R5 horizon.
8B.10. Simple shear on B4_bt to restore offset of R5 horizon.
8B.11. Trishear on Fault B4, with separation -1000 m; trishear angle 80°; trishear angle offset 0.9; propagation/slip ratio 5; trishear zones 2; angular shear 2°; position of the virtual fault tip for restoration set at the seabed.
8B.12. Trishear on Fault B5, with separation -200 m; trishear angle 90°; trishear angle offset 0.9; propagation/slip ratio 5; trishear zones 2; no angular shear; position of the virtual fault tip for restoration set halfway between R4 and R5 horizon levels.
8B.13. Trishear on Fault B6_fs, with separation -70 m; trishear angle 50°; trishear angle offset 0.5; propagation/slip ratio 1; trishear zones 1; no angular shear; position of the virtual fault tip for restoration set halfway between R4 and R5 horizon levels.
8B.14. Trishear on Fault B6, with separation -400 m; trishear angle 70°; trishear angle offset 0.5; propagation/slip ratio 3; trishear zones 1; angular shear 2°; position of the virtual fault tip for restoration set at the seabed.
8B.15. Simple shear on B6 backthrust to restore offset of R5 horizon.
8B.16. Trishear on Fault B7, with separation -500 m; trishear angle 50°; trishear angle offset 0.7; propagation/slip ratio 5; trishear zones 1; angular shear 2°; position of the virtual fault tip for restoration set at the seabed.
8B.17. Trishear on Fault B8_fs, with separation -500 m; trishear angle 50°; trishear angle offset 0.5; propagation/slip ratio 5; trishear zones 1; angular shear 2°; position of the virtual fault tip for restoration set at the seabed.

Result of above shown by Figure 8B (main text) – Stage 2.

8A.1. Decompaction of the sediment sequence between R4 and R5.
8A.2. Trishear on Fault B1, with separation -1500 m; trishear angle 60°; trishear angle offset 0.4; propagation/slip ratio 7; trishear zones 4; angular shear 2°; position of the virtual fault tip for restoration set at halfway between R5 and R5B horizon levels.
8A.3. Trishear on Fault B1_bt, with separation -50 m; trishear angle 50°; trishear angle offset 0.5; propagation/slip ratio 3; trishear zones 1; angular shear -1°; position of the virtual fault tip for restoration set at halfway between R5 and R5B horizon levels.
8A.4. Trishear on Fault B2, with separation -1000 m; trishear angle 50°; trishear angle offset 0.5; propagation/slip ratio 5; trishear zones 1; angular shear 2°; position of the virtual fault tip for restoration set at halfway between R5 and R5B horizon levels.
8A.5. Trishear on Fault B3, with separation -2000 m; trishear angle 60°; trishear angle offset 0.7; propagation/slip ratio 5; trishear zones 1; angular shear 2°; position of the virtual fault tip for restoration set at halfway between R5 and R5B horizon levels.
8A.6. Trishear on Fault B4_fs, with separation -3000 m; trishear angle 50°; trishear angle offset 0.7; propagation/slip ratio 5; trishear zones 2; angular shear 2°; position of the virtual fault tip for restoration set at the seabed.

8A.7. Trishear on Fault B8, with separation -500 m; trishear angle 50°; trishear angle offset 0.5; propagation/slip ratio 2; trishear zones 1; no angular shear; position of the virtual fault tip for restoration set at the seabed.
8A.8. Trishear on Fault B9, with separation -700 m; trishear angle 50°; trishear angle offset 0.5; propagation/slip ratio 1; trishear zones 1; no angular shear; position of the virtual fault tip for restoration set at the seabed.

Result of above shown by Figure 8A (main text) – Stage 1.

Text S4. Progressive Retro-Deformation Restoration Steps for Profile C (PEG09-009), Figure 8

Values for parameters provided below were achieved through interactive trial and error. Starting model is the structural interpretation for the present day (Figure 9E). Steps indicate process undertaken to model previous states of deformation from Figure 9E to 9A:

Stage 5 (Figure 9E) is present-day.

9D.1. Trishear on secondary C1 fault, with separation -21 m; trishear angle 50°; trishear angle offset 0.5; propagation/slip ratio 4; trishear zones 1; no angular shear; position of the virtual fault tip for restoration set halfway between R4 and R5 horizon levels.
9D.2. Trishear on Fault C4, with separation -10 m; trishear angle 120°; trishear angle offset 0.9; propagation/slip ratio 4; trishear zones 3; no angular shear; position of the virtual fault tip for restoration set at the R5 hanging-wall level.
9D.3. Offset of horizon R3 by minor faulting CMF1 restored using simple shear.

Result of above shown by Figure 9D (main text) – Stage 4.

9C.1. Decompaction of the sediment sequence between R0 and R3.
9C.2. Trishear on upper backthrust of Fault C1, with separation -30 m; trishear angle 70°; trishear angle offset 0.5; propagation/slip ratio 0.25; trishear zones 1; no angular shear; position of the virtual fault tip for restoration set halfway between R4 and R5 horizon levels.
9C.3. Trishear on secondary C1 fault, with separation -44 m; trishear angle 60°; trishear angle offset 0.9; propagation/slip ratio 0.1; trishear zones 3; no angular shear; position of the virtual fault tip for restoration set halfway between R5 and R5B horizon levels.
9C.4. Trishear on Fault C1, with separation -250 m; trishear angle 50°; trishear angle offset 0.5; propagation/slip ratio 6; trishear zones 7; angular shear 2°; position of the virtual fault tip for restoration set just under R7 horizon level.
9C.5. Remaining slip on Fault C1 restored via simple shear.
9C.6. Remaining slip on minor faulting CMF1 restored using simple shear.

9C.7. Trishear on Fault C2, with separation -350 m; trishear angle 50°; trishear angle offset 0.8; propagation/slip ratio 3; trishear zones 6; angular shear 2°; position of the virtual fault tip for restoration set at the detachment point.
9C.8. Remaining slip on Fault C2 restored via simple shear.
9C.9. Minor faulting CMF2 restored using simple shear.
9C.10. Trishear on Fault C4, with separation -300 m; trishear angle 70°; trishear angle offset 0.8; propagation/slip ratio 2; trishear zones 2; angular shear 2°; position of the virtual fault tip for restoration set just below the R5 horizon level.
9C.11. Simple shear on Fault C4 with separation -50.
9C.12. Simple shear on Fault C4_bt to restore offset of R4.
9C.13. Simple shear on C5 backthrust to restore offset of R4.
9C.14. Trishear on Fault C5, with separation -1000 m; trishear angle 50°; trishear angle offset 0.7; propagation/slip ratio 2; trishear zones 2; angular shear 2°; position of the virtual fault tip for restoration set halfway between R5 footwall and hanging-wall levels.

Result of above shown by Figure 9C (main text) – Stage 3.

9B.1. Decompaction of the sediment sequence between R3 and R4.
9B.2. Simple shear on Fault C3 to restore offset of R5.
9B.3. Trishear on Fault C4_bt, with separation -400 m; trishear angle 40°; trishear angle offset 0.6; propagation/slip ratio 10; trishear zones 1; angular shear 2°; position of the virtual fault tip for restoration set just below the R5 horizon level.
9B.4. Trishear on Fault C4, with separation -500 m; trishear angle 70°; trishear angle offset 0.8; propagation/slip ratio 10; trishear zones 1; no angular shear; position of the virtual fault tip for restoration set just above the R5 horizon level.
9B.5. Trishear on Fault C5_fs, with separation -300 m; trishear angle 70°; trishear angle offset 0.7; propagation/slip ratio 10; trishear zones 1; no angular shear; position of the virtual fault tip for restoration set just below the R4 horizon (seabed) level.
9B.6. Trishear on Fault C5, with separation -400 m; trishear angle 40°; trishear angle offset 0.6; propagation/slip ratio 10; trishear zones 1; angular shear 2°; position of the virtual fault tip for restoration set just below the R5 horizon level.

Result of above shown by Figure 9B (main text) – Stage 2.

9A.1. Decompaction of the sediment sequence between R4 and R5.
9A.2. Trishear on Fault C4, with separation -600 m; trishear angle 55°; trishear angle offset 0.45; propagation/slip ratio 10; trishear zones 1; angular shear 2°; position of the virtual fault tip for restoration set just below the R5B hanging-wall level.
9A.3. Trishear on Fault C5_fs, with separation -1400 m; trishear angle 70°; trishear angle offset 0.5; propagation/slip ratio 1; trishear zones 1; angular shear 2°; position of the virtual fault tip for restoration set just below the R5 footwall level.

9A.4. Trishear on Fault C5, with separation -400 m; trishear angle 40°; trishear angle offset 0.6; propagation/slip ratio 10; trishear zones 1; angular shear 2°; position of the virtual fault tip for restoration set just below the R5 level.

Result of above shown by Figure 9A (main text) – Stage 1.

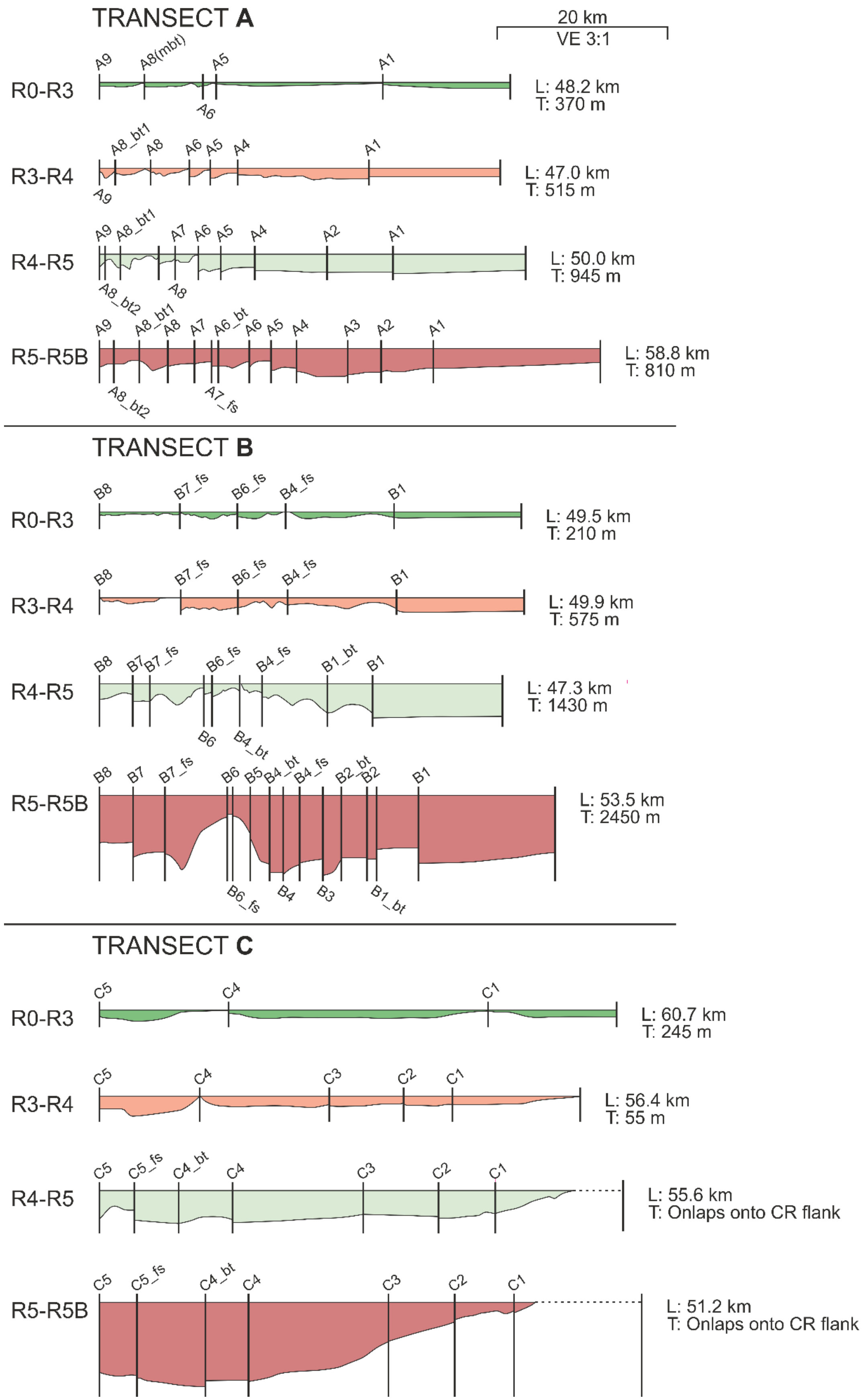
TRANSECT A
20 km
VE 3:1
R0-R3
A9
A8(mbt)
A5
A1
A6
L: 48.2 km
T: 370 m
R3-R4
A8_bt1
A8
A6
A5
A4
A1
A9
L: 47.0 km
T: 515 m
R4-R5
A9
A8_bt1
A7
A6
A5
A4
A2
A1
A8_bt2
A8
L: 50.0 km
T: 945 m
R5-R5B
A9
A8_bt1
A8
A7
A6_bt
A6
A5
A4
A3
A2
A1
A8_bt2
A7_fs
L: 58.8 km
T: 810 m
TRANSECT B
R0-R3
B8
B7_fs
B6_fs
B4_fs
B1
L: 49.5 km
T: 210 m
R3-R4
B8
B7_fs
B6_fs
B4_fs
B1
L: 49.9 km
T: 575 m
R4-R5
B8
B7
B7_fs
B6_fs
B4_fs
B1_bt
B1
B6
B4_bt
L: 47.3 km
T: 1430 m
R5-R5B
B8
B7
B7_fs
B6
B5
B4_bt
B4_fs
B2_bt
B2
B1
B6_fs
B4
B3
B1_bt
L: 53.5 km
T: 2450 m
TRANSECT C
R0-R3
C5
C4
C1
L: 60.7 km
T: 245 m
R3-R4
C5
C4
C3
C2
C1
L: 56.4 km
T: 55 m
R4-R5
C5
C5_fs
C4_bt
C4
C3
C2
C1
L: 55.6 km
T: Onlaps onto CR flank
R5-R5B
C5
C5_fs
C4_bt
C4
C3
C2
C1
L: 51.2 km
T: Onlaps onto CR flank

Figure S1 (previous page). Bedding-perpendicular thickness of units R0–R3, R3–R4, R4–R5, and R5–R5B in depth-converted transects of profiles A (Figure 7F), B (Figure 8F), and C (Figure 9F). Stratigraphy as in Figure 2. Thickness is measured at intervals of 100 m and plotted for layers restored to a putative horizontal datum in between the thrust faults. Measurements performed using the section analysis tool of MOVE Midland Valley (2014). Fault labels as in Figures 3 to 9. The measurements show the regional westward thickening of units, perturbed by superposed thickness variations adjacent to thrust faults.

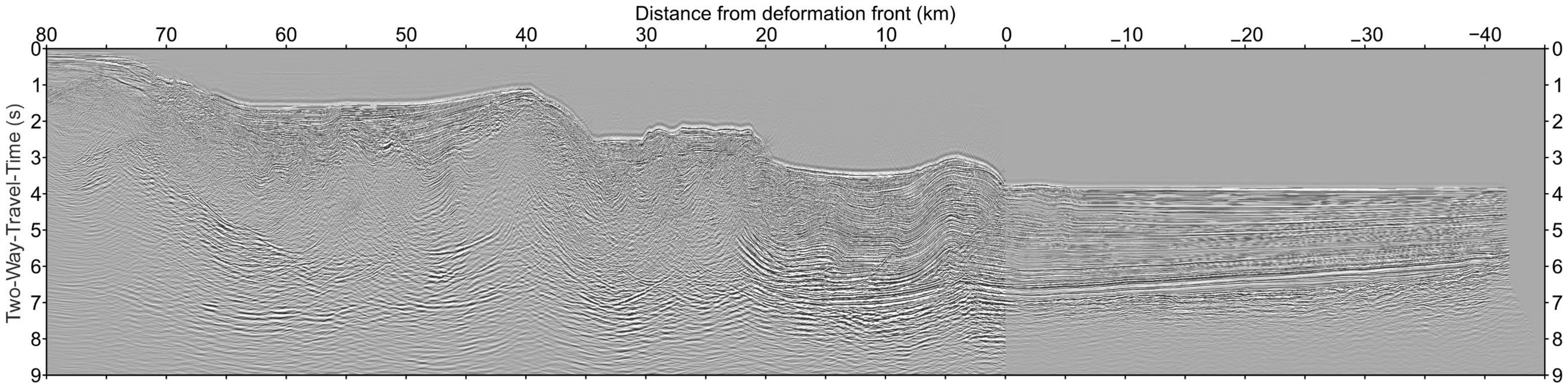

Figure S2. Seismic Profile A (MH44) at 2× vertical exaggeration (based on water velocity at the seabed). Note that gain has been increased landward of the deformation front to enhance visibility of features beneath the prism.

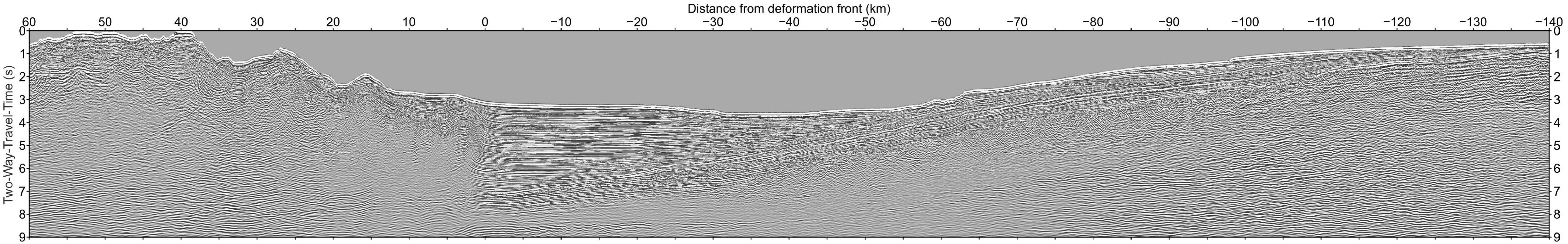

Figure S3. Seismic Profile B (PEG09-017) at 2× vertical exaggeration (based on water velocity at the seabed).

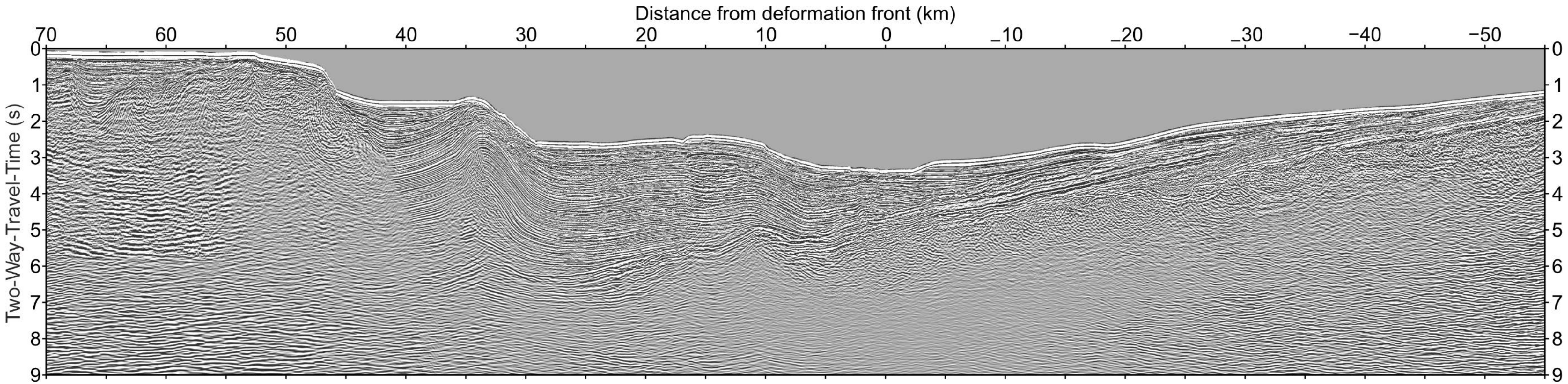

Figure S4. Seismic Profile C (PEG09-009) at 2× vertical exaggeration (based on water velocity at the seabed).