

REVISED GEOLOGICAL MAP
OF THE NELSON-
RICHMOND URBAN AREA



M.R. Johnston, F. Ghisetti, P. Wopereis 2024

The following is modified from the Supplemental File 1 of the paper

Structural evolution, segmentation and activity of the onshore-offshore Waimea-Flaxmore Fault System in south-eastern Tasman Bay, South Island, New Zealand

Francesca C. Ghisetti^a, Mike R. Johnston^b, Paul Wopereis^c, Richard H. Sibson^d

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The description refers to the “Revised Geological Map of the Nelson-Richmond Urban Area”, and associated Stratigraphic Column and Cross Sections, all downloadable from the main web page.

Geometry and activity of the Waimea-Flaxmore Fault System in onshore Nelson

The Waimea-Flaxmore Fault System (W-FFS) is the main range-front structure (Johnston 1979; 1981; 1990) within a set of closely spaced reverse faults (comprising the major Tahunanui, Flaxmore, Waimea, Eighty-Eight and Whangamoia faults) that extend with NNE-SSW orientation from the intersection with the Wairau Fault to the Tasman Bay coastline.

Faults of this system can be correlated to equivalent N-S structures in the region of the Alpine Fault “bend”, that are dextrally offset c. 50 km by the Wairau Fault (Ghisetti 2022, see Figure 1).

North of the Wairau Fault, the W-FFS imbricates Late Paleozoic-Early Mesozoic Eastern Province rocks (cf. Mortimer et al. 2014), comprising (in order of tectonic superposition) the Drumduan, Brook Street, Murihiku, Dun Mountain-Maitai and Caples terranes, which are thrust over the Median Batholith and overlying sedimentary sequences outcropping in the Moutere Depression (Figure 1). North of Nelson, the W-FFS is again partially exposed in D’Urville Island (Figure 1). The width of the W-FFS in the south (at the intersection with the Wairau Fault) is only a few hundred metres, but in Nelson City is >5 km.

The oldest sedimentary formation overlying basement rocks within the W-FFS is the Bishopdale Conglomerate (see stratigraphic column), of inferred late Early Cretaceous age (95-90 Ma) (Ghisetti et al. 2020), recording deposition in terrestrial basins that formed during multi-stage continental rifting of the eastern Gondwana margin (c. 105-83 Ma), prior to Late Cretaceous-Paleocene crustal extension and separation of Zealandia (Nathan et al. 1986; Laird and Bradshaw 2004; Adams et al. 2017; Strogon et al. 2017; Tulloch et al. 2019; Barrier et al. 2020). Following a long hiatus, the overlying Marsden Coal Measures (37-35 Ma) were

deposited during late stages of Eocene extension and post-rift subsidence of the Zealandia crust (Kamp 1986; Mortimer et al. 2017), with ensuing marine transgression and sedimentation of the lower Jenkins Group in the time interval 35-25 Ma (Stratigraphic Column). This sequence is overlain by the siliciclastic Upper Jenkins Group. In the Nelson-Richmond urban area, the youngest deposits (Tadmor Group, see Stratigraphic Column) are the terrestrial Port Hills and Moutere gravel formations of Late Miocene and Pliocene-Early Pleistocene age and marine and terrestrial Late Quaternary sediments.

The Revised Geological Map of the Nelson-Richmond Urban Area (v4-2024) and associated Cross Sections show the complex interlinking of distinct fault segments and the presence of multiple, sub-parallel splays along the W-FFS (Ghisetti et al. 2018, 2020; Johnston et al. 2022).

The lowest and westernmost splay is the Tahunanui Fault (Sections 2-5) that superposes Cenozoic formations outcropping on the steep western limb of the Port Hills Syncline onto late Quaternary sands and gravels and (as confirmed by drilling) Moutere Gravel. The Tahunanui Fault terminates to the south against the Flaxmore Fault, whereas to the north it goes offshore (see Geological Map).

The Flaxmore Fault has two major splays (West and East Flaxmore faults, cf. Flaxmore Fault Zone in sections 1-6) within Nelson City, bounding a ≤ 500 m wide wedge of vertically sheared late Early Cretaceous (?) Bishopdale Conglomerate. The implication is that the Flaxmore Fault includes inherited syn-rift normal faults that have undergone late reverse-slip reactivation (Ghisetti et al. 2018; 2020).

In the Bishopdale area of Nelson City, the W-FFS crosscuts the E-W, S-dipping Grampian Fault, and south of it the East Flaxmore Fault abruptly changes from reverse to normal (hanging wall Port Hills Gravel downfaulted against older formations in the footwall) and truncates the West Flaxmore Fault (cf. sections 1-3). This localised switch to normal slip separation can be related to near-surface tensional stresses in unconsolidated Port Hills Gravel, resulting in an increase of the vertical principal stress (cf. Bartholomew and Whitaker 2010), with gravitative collapse of the folded hanging wall (Ghisetti et al. 2020).

Normal components of slip along the East Flaxmore Fault terminate at its intersection with the Tahunanui faults and south of it one single buried strand of the Flaxmore Fault is inferred from discontinuous outcrops of Bishopdale Conglomerate and the superposition of Port Hill Gravel onto Moutere Gravel and Quaternary deposits.

In the Richmond area, the buried strand of the Flaxmore Fault terminates against the adjacent Waimea Fault, but further south, at the eastern margin of the Moutere Depression, the Flaxmore Fault is again in outcrop (Johnston 1990, cf. Figure 1).

Mutually intersecting fault splays also characterise the Waimea Fault in the Richmond-Nelson area. North of the Grampian Fault, Richmond Group and Maitai rocks are imbricated above units of the Jenkins Group (Marsden Coal Measures and Wakatu Formation) and thrust over Brook Street Terrane. South of the Grampian Fault, the Richmond Group overlies slivers of Bishopdale Conglomerate and Marsden Coal Measures and is thrust over Port Hills and Moutere gravels.

Quaternary activity of the Flaxmore Fault is inferred from morphological escarpments within Quaternary and Holocene deposits (Johnston 1979; Fraser et al. 2006; Johnston and Nicol 2013), as also highlighted by LiDAR surveys (Ghisetti et al. 2020, cf. Photo Gallery in the web page). A trench recently excavated at the toe of the range front in the south of Nelson City has revealed c. 1.7 m of reverse separation of the Pleistocene-Holocene Stoke fan and associated alluvium (Wiffin 2023). Elsewhere in the urban area differences in the height of old erosion surfaces and terrace remnants in valley floors (Johnston 1979) also suggest both vertical and minor dextral components of displacement along the East Flaxmore Fault.

Paleo-seismic ruptures in fault trenches show the occurrence of at least three seismic ruptures on the Waimea Fault, with $M > 6.5$ in the last 20 ka, and average slip rates of 0.5 mm/yr (Fraser et al. 2006; Johnston and Nicol 2013; Seebeck et al. 2023).

E-W faults mapped in the Nelson city area (e.g. Grampian and Hira faults) and other E-W faults within the imbricated terranes of the Nelson region (Rattenbury et al. 1998) appear to be inherited basement structures that were not reactivated during Miocene-Quaternary shortening and do not cut across the active fault of the W-FFS (Ghisetti et al. 2020).

The ENE-WSW Bishopdale Fault in central Nelson also appears to be confined within the panel bounded by the East Flaxmore and Waimea faults. However, in contrast with the other E-W faults, there is documented evidence of Holocene activity, with dextral separation of ridge crests by c. 30 m. (Bruce 1962; Fraser et al. 2006; Johnston and Nicol 2013). The sub-orthogonal orientation of the Bishopdale Fault relative to the dominant NE-SW structural fabric and its strike-slip components are consistent with its role as a lateral ramp (cf. Ghisetti et al. 2020) during events of contemporaneous Holocene rupture of the Flaxmore and Waimea faults documented by paleoseismic data (Fraser et al. 2006; Johnston and Nicol 2013).

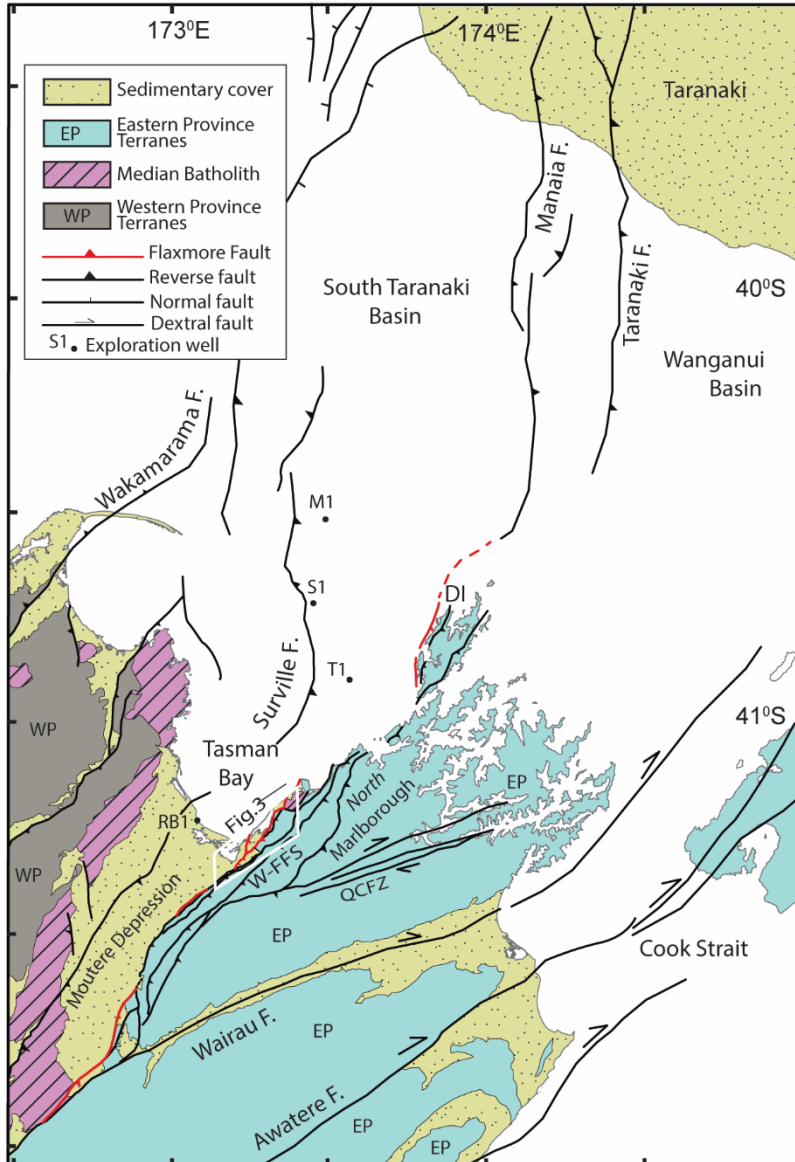


Figure 1 - Regional location of the Waimea-Flaxmore Fault System (W-FFS). The range front fault is marked in red. The Nelson-Richmond urban area mapped in Figure 3 is shown within the white quadrangle. Figure 14 shows our interpretation of the offshore trace of the W-FFS in eastern Tasman Bay. DI: D'Urville Island. QCFZ: Queen Charlotte Fault Zone. M1: Motueka-1; S1: Surville-1, T1: Tuatara-1, RB1: Ruby Bay-1 exploration wells.

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