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PALEOSEISMOLOGY, SEISMIC HAZARD AND VOLCANO-TECTONIC INTERACTIONS IN THE TONGARIRO VOLCANIC CENTRE, NEW ZEALAND

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By

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To my family and Denis Avellán, who stand by me, no matter what.

I love you!

‘It is not the mountain we conquer, but ourselves’. Sir Edmund Hillary

With passion, patience and persistence…
Abstract

At the southern part of the Taupo Rift, crustal extension is accommodated by a combination of normal faults and dike intrusions, and the Tongariro Volcanic Centre coexists with faults from the Ruapehu and Tongariro grabens. This close coexistence and volcanic vent alignment parallel to the regional faults has always raised the question of their possible interaction. Further, many periods of high fault slip-rate seem to coincide with explosive volcanic eruptions. For some periods these coincidences are shown to be unrelated; however, it remains important to evaluate the potential link between them. In the Tongariro Graben, the geological extension was quantified and compared to the total geodetic extension, showing that 78 to 95% of the extension was accommodated by tectonic faults and only 5 to 22% by dike intrusions. Within the latter, 4 to 5% was accommodated by volcanic eruptions and 18 to 19% by arrested dike intrusions, with an unknown percentage of hybrid extension. Short-term variations in fault slip-rates and volcanic activity for the last 100 ka in the Tongariro Volcanic Centre may have been influenced by static stress transfer between adjacent faults (within <20 km from the source) and dike intrusions (within <10 km), or by fluctuations in magma input through time. The amount of magma involved in the rifting process will condition the predominant extension mechanism and thus influence the predominant type of volcano-tectonic interaction. A record of volcanic and seismic activity for the last 250 ka was assembled, from new and published studies. This was used to analyse the spatio-temporal associations between volcanic and seismic activity in the southern Taupo Rift. Data on the faulting history, slip-rate variation and seismic hazard of the Upper Waikato Stream, Wahianoa, Waihi and Poutu faults formed the core of the analysis. These faults are capable of producing a $M_W$ 7.2 earthquake with a single-event displacement of 2.9 m, posing an important hazard to the region. Data gathered in this study provides an update to the National Seismic Hazard Model for New Zealand.
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Figure S2. Faults in section 1 in the Upper Waikato Stream. A, Image from Cyclone software showing fault 3 on ‘wall b’ and its general stratigraphy. B, Fault 3 on ‘wall c’ showing a three-step fault scarp. C, D & E, Southern corner of ‘wall b’ showing exposure of fault 4 and general stratigraphy. F, Exposure of fault 5 on ‘wall c’ showing multiple-step fault on R11 lahars. G, Cyclone measurement of fault 5 on ‘wall b’ on R11 lahars. H, Exposure of the termination of fault 5 on the Hokey Pokey eruptive period on ‘wall c’. I, ‘Wall d’ with a multiple-step fault (6) cutting through R11 lahars. J, Fault 7 exposure cutting through elephant surge up to R11 lahars with a multiple-event step-fault. See Figure 14 for further information about stratigraphic units.

Figure S3. A, Fault 10/4_1:030/65SE to 055/85NW normal fault, vertical offset ~1 m; and a secondary fault 010/76NW with 0.77±0.16 m of net-slip. The stratigraphic position and the fault termination of this fault are uncertain. B, 10/4_2: normal step-fault cutting through the Papakai Formation. C, 10/4_4a: fault exposure cutting through R13 lahars and older deposits. D, 10/4_4a: Fault exposure 10 m above the river level. E, 10/4_4b: Fault exposure 2 m above the river level cutting through the Okataina sourced Rotoehu Ash (64 ka), R13 lahars, marker unit 3 and R14 lahars. F, 10/4_5: normal fault cutting R15 lahars and older deposits. G: 10/4_6: fault exposure of a normal fault cutting R13 lahars and older deposits. H, 11/4_4 and 11/4_5: faults and fractures that cut through greywackes and younger tephras, cropping out by the river level.

Figure S4. A, Wahianoa Fault outcrop ‘Tong 23’ in the Karioi Forest, section 3, showing antithetic faults (field location shown on Figure 21A). The fault planes are plotted in stereographic (lower hemisphere) projection and superimposed rose diagrams of fault strike frequency (right-hand rule). See Figure 14 for more information about the stratigraphy. B, Wahianoa Fault cutting across and andesite lava flow of the Mangawhero Formation.

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List of abbreviations

BP Before Present
cal calibrated
CFC Coulomb failure criterion
DSM Digital Surface Model
GIS Geographic Information System
GNS Institute of Geological and Nuclear Sciences
GPa Gigapascal
GPS Global Positioning System
ka Thousand years
Ma Million years
m a.s.l. Metres above the sea level
Mt. Mount
M_w Moment magnitude
PM Pahoka-Mangamate
RTK Real Time Kinematic
TgVC Tongariro Volcanic Centre
TVC Tongariro Volcanic Complex
TLS Terrestrial Laser Scanning
TVZ Taupo Volcanic Zone
UWS Upper Waikato Stream
VEI Volcanic Explosivity Index