A history of fault activity in the vicinity of Aotearoa's supervolcano

Prepared by: James Muirhead[1*], Alex Gold[1], Pilar Villamor[2], Colin Wilson[3]

1: University of Auckland

2: Earth Sciences New Zealand

2: Victoria University of Wellington

*j.muirhead@auckland.ac.nz

May 4 2026

With funding support from

Natural Hazards Commission
Toka Tū Ake

Acknowledgements

This project is supported by a Natural Hazards Commission Toka Tū Ake biennial research fund. Support is provided by University of Auckland (Muirhead and Gold), Earth Sciences New Zealand (Villamor, Coffey) and Victoria University of Wellington (Wilson). Additional funding was provided by a University of Auckland Research Development Fund (award no. 3726746) award to Muirhead. Alex Gold is supported by a University of Auckland Doctoral Scholarship. MBIE SSIF co-funded Villamor's and Coffey's time. Katharine Gilchrist and Brendan Hall (University of Auckland) provided field support, including UAV image collection and structure-from-motion modelling. Both Hema Wihongi and Erin McEwan (Natural Hazards Commission, Toka Tu Ake) are thanked for reviewing this document, and Hema Wihongi is also acknowledged for their contribution to the Mātauranga Māori framing of this report. We acknowledge Contact Energy Ltd, Tau Ke Farming Ltd, and LINZ for allowing access to land for fault investigations in this study.

Executive summary

Although the history of volcanic eruptions from Taupō volcano is well documented, the history of earthquake activity in this region is poorly understood. To address this issue, our team conducted analyses along major fault lines near Taupō volcano to examine their earthquake histories and whether fault activity is associated with eruptions from Taupō volcano. Our research provides constraints on the earthquake recurrence intervals (maximum of 1,475 years) of the Kaiapo and Whakaipō Faults, which will be incorporated into the New Zealand Active Fault Database and future editions of the National Seismic Hazard Model. We also demonstrate that large eruptions from Taupō may be preceded by episodes of fault rupture. Our demonstration of strong volcano-tectonic coupling at Taupō volcano highlights the need for future research that will improve our understanding of, and capacity to respond to, multi-hazard scenarios at Taupō volcano, particularly when considering episodes of heightened volcanic unrest.

Abstract

Although the history of volcanic eruptions from Taupō volcano is well documented, the history of earthquake activity in this region is poorly understood. To address this issue, our team conducted field and paleoseismic analyses along major normal faults of the North Taupō Fault Zone (Kaiapo and Whakaipō Faults) to examine their earthquake histories and whether fault activity is associated with eruptions from Taupō volcano. Our analyses reveal eight earthquake events on both the Kaiapo and Whakaipō Faults since eruption of the Karapiti volcanic layer at 11.8 ka, supporting a maximum earthquake recurrence of 1,475 yrs. Vertical displacement rates on the Kaiapo Fault likely exceed 1.67 mm/yr. Furthermore, we identify syn-eruptive faulting during 4 eruptions from Taupō volcano, with the 232 CE eruption demonstrating the greatest number of interactions with the North Taupō Fault Zone. Our results demonstrate strong volcano-tectonic coupling, supporting a multi-hazard framework for Taupō volcano..

Keywords

Taupō volcano, earthquake hazard, volcanic hazard, multi-hazard, volcano-tectonic interactions

Introduction

Taupō supervolcano, one of Earth's most productive silicic volcanoes (Barker et al., 2021), is also a region of persistent earthquake activity. Settlements around Lake Taupō have experienced historic surface-rupturing earthquakes along a series of NNE-trending normal faults (the North Taupō Fault Zone) that intersect the northern lake shore (Gold et al., 2026). The juxtaposition of active normal faulting and silicic caldera volcanism renders this region liable to major volcano-tectonic hazards, where volcanic activity may be triggered in response to fault rupture, or a major earthquake could be triggered by pressure changes in the magmatic system (Muirhead et al., 2022). Such interactions also align with a whakapapa-based understanding of te taiao. Mātauranga Māori recognises that domains such as whenua, wai, ahi, and Rangi are interconnected, and personified through whakapapa, with disturbance in one domain affecting all others. This reinforces the need for holistic, place-based approaches to hazard resilience, including recognition of interconnected (multi-hazard) events.

Although the timing and magnitude of young volcanic eruptions from Taupō are well documented (Wilson, 1993), the paleoseismic history is comparatively poorly understood. Fault slip rates and earthquake recurrence intervals are only loosely quantified, as are the spatio-temporal relationships between earthquakes and activity associated with unrest and eruption (Muirhead et al., 2022). To address this issue, our team has conducted field and paleoseismic analyses along major normal faults of the North Taupō Fault Zone (Figures 1 and 2) to examine their earthquake histories and whether fault activity is associated with eruptions from Taupō volcano. Our objectives were to answer two outstanding questions critical to our understanding of the volcanic and earthquake hazard in the Taupō region:

(1) What are the slip histories and recurrence intervals of major faults in the North Taupō Fault Zone?

(2) How often are fault-rupturing earthquakes in the North Taupō Fault Zone associated and linked with volcanic activity?

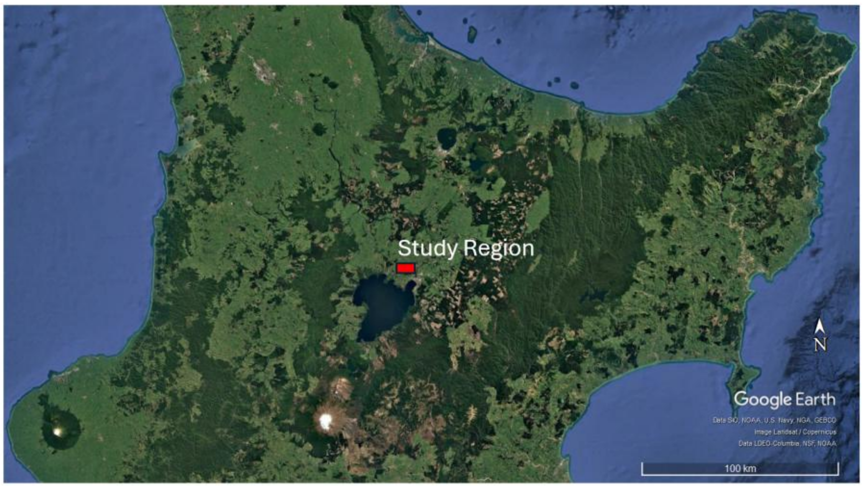

Figure 1: Google Earth image showing the location of our study region (red box: see also Figure 2).

Collaboration and stakeholder engagement

This research represents a collaborative effort between researchers from the University of Auckland (James Muirhead, Alex Gold), Victoria University of Wellington (Colin Wilson), and Earth Sciences New Zealand (Pillar Villamor, Genevieve Coffey). The fault systems examined in this study occur across land owned and used by LINZ, Contact Energy Ltd, and Tau Ke Farming Ltd. Our team worked with these stakeholders to acquire permission to access their land, and reported on our results through online presentations and written reports. Our team shared and discussed results with Emergency Managers from Taupō District Council and Waikato Civil Defence and Emergency Management during trenching site visits in December 2025. Throughout the project, our team has worked closely with mana whenua from Ngati Tuwharetoa (e.g., Gayle Leaf), providing presentations at our trenches, sharing our understanding of the volcanic history, and also working together to engage local communities through school visits (Wairakei Primary School).

Methodology

To constrain the paleoseismic history of the major faults of the North Taupō Fault Zone, we conducted remote- and field-based analyses. We used the New Zealand Active Fault Database 2.0 (Morgenstern et al., 2024) and a 1 m-resolution LiDAR digital elevation model (DEM) (Toitū Te Whenua – Land Information New Zealand, 2025) to identify and map the Kaiapo and Whakaipō Faults, and their associated splay structures. This desktop study allowed us to examine the vertical displacement patterns along these faults and facilitated the identification of the ideal sites for paleoseismic trenching. Additionally, we utilised data from previous paleoseismic trenching campaigns, analysis of paleoshorelines at Whakaipō Bay (see Gold et al., 2026), and both published and unpublished literature to contextualise the results from the National Hazard Commission-funded trenches (Figure 2).

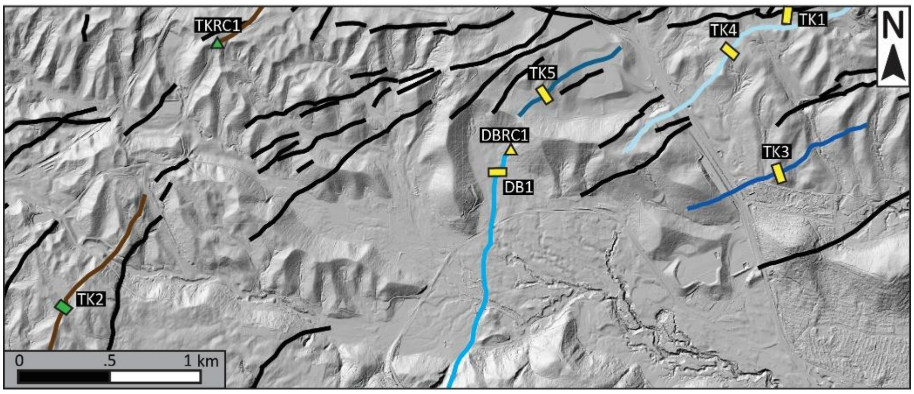

Figure 2: Hillshade map of the study area. Red lines indicate fault segments, and blue and brown lines represent the strands of the Kaiapo Fault and Whakaipō Faults, respectively, investigated in this study. Rectangles and triangles represent trenches and roadcut outcrops, respectively, analysed in this study.

Initial field analysis was conducted with Ground Penetrating Radar (GPR) (MALÅ systems) using a 160 MHz antenna, deployed across and perpendicular to the Kaiapo and Whakaipō Faults. GPR lines were processed using the open-source GPR processing and visualisation software GPRPy (Plattner, 2020). This analysis revealed both the fault structure beneath the surface and the thickness of the volcanic tephras from Taupō volcano, which are ubiquitous in the North Taupō Fault Zone area (Wilson, 1993). Lastly, visual analysis of fault-scarp morphologies was conducted in the field. This combined approach, using desktop-based, geophysical, and traditional geomorphic analysis, ensured that the sites chosen for trenching would reveal the fault plane and a range of offset volcanic layers.

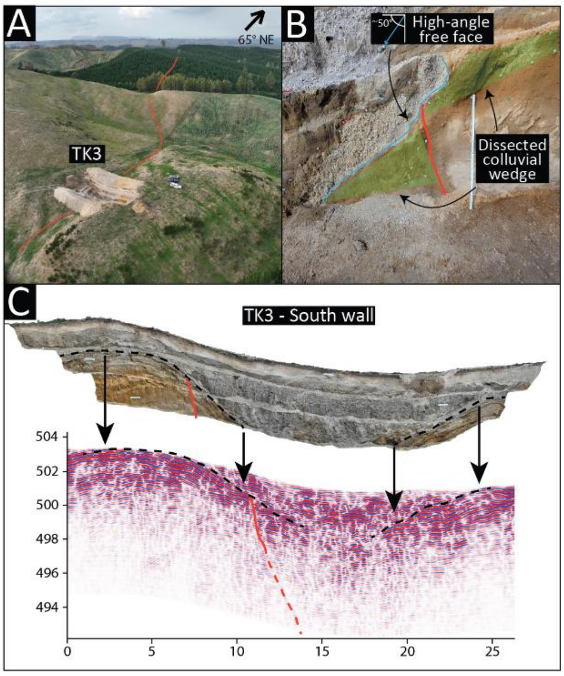

Figure 3: (A) Aerial image of TK3 trench. Red line indicates fault trace of the Kaiapo Fault. (B) Example of stratigraphic relationships between faults and volcanic layers in TK3, with a volcanic unit draping a high-angle free face and a faulted colluvial wedge. (C) Ortho-mosaic image of TK3 trench wall and corresponding GPR survey line. Black dotted line indicates the base of Taupō ignimbrite, and red lines indicate the fault.

This project involved the excavation and analysis of a total 5 paleoseismic trenches (DB1,TK2, TK3, TK4, TK5) and two road cuts (TKRC1 and DBRC1), which were excavated to measure displacements of the volcanic stratigraphy across the Kaiapo and Whakaipō Faults (Figures 2 and 3). The trenches were 6-10 m wide, 30-50 m long and 3-4.5 m deep, and were excavated perpendicular to the strike of fault strands (Figure 3a). Due to the infilling of valleys and topographic depressions by eruptive products from Taupō volcano, sites on topographic highs were prioritised (Figure 2 and 3a). The volcanic stratigraphy within each trench was then photographed using a UAV, and a 3D model and orthomosaic of each trench wall was created using the structure-from-motion software Agisoft Metashape 1.7(Figure 3c)(see also Gold et al., 2026). The orthomosaic images were printed and used as templates to record and log the stratigraphy of the trenches. By observing how fault planes interact, dissect, and form geometric relationships with the volcanic stratigraphy, we determine the history and timing of earthquake events on these fault lines. We note that shallow paleoseismic trenches record only paleoearthquakes that produced identifiable surface-ruptures. Consequently, past earthquakes that either did not rupture the surface or produced small surface displacements (i.e., a few cm or less) are likely missed in our records. Our approach thus provides a record of the largest paleoearthquakes and minimum number of events along these fault strand.

The criteria used for identifying syn-eruptive fault displacements were based on Villamor et al. (2011). We define syn-eruptive volcanic events as any fault rupture or instance of shaking that occurred immediately prior to or during a volcanic eruption. Seismic events of sufficient magnitude to produce regional shaking, preserved as mass movements or tephra reorganisation, were interpreted as tectonic in origin rather than volcanic tremor.

Additional GPR surveys were conducted on the day of trenching above the prospective trench sites. This allowed comparison of the volcanic stratigraphy revealed in the trench with that in the GPR surveys (Figure 3). Compared to the ~4.5 m-deep trenches, GPR surveys conducted in this region typically reached depths of ~8 m. Therefore, by matching the GPR survey sections to the stratigraphy revealed in the trenches, the extent of the mapped stratigraphy could be extended beneath the trenches (Figure 3c). This process was further aided by auguring conducted at the base of the trenches to determine the relative elevation of the contacts between major volcanic units.

Results and discussion

Analysis of paleoseismic trenches DB1, TK2, TK3, TK4, TK5 and two road cuts (TKRC1 and DBRC1) (Figure 3.1) revealed eight fault rupturing events on both the Kaiapo and Whakaipō Faults since eruption of the Karapiti volcanic layer at 11.8 ka (Wilson, 1993). Therefore, both the Kaiapo and Whakaipō Faults have maximum earthquake recurrences of 1,475 years (i.e., 11,800 years / 8 events). Additionally, across multiple trenches (TK3 and TK5), the upper surface of the Ōruanui ignimbrite (25.5 ka: Vandergoes et al., 2013) is displaced more than the Karapiti tephra, facilitating at least one additional earthquake event since ~25,500 years.

Recorded displacements in trenches and roadcuts enable the calculation of displacement rates (mm/yr) along the Kaiapo Fault. Older tephra units (typically pre-Opepe tephra; Unit E, 9.9 ka, Wilson, 1993) were rarely observed in fault hanging walls within trenches, and thus augering was conducted to intersect these lower units to allow measurements of the displacement of the entire post-Ōruanui tephra package. In all, displacements on the Karapiti tephra support a vertical displacement rate of 1.67 mm/yr over the past 11,800 yrs on the Kaiapo Fault. As some strands of the Kaiapo Fault could not be interrogated in this study, this displacement rate should be treated as a minimum value.

Utilising techniques for identifying syn-eruptive seismic events by Villamor et al. (2011), and paleoshoreline analyses outlined by Gold et al. (2026), we identified 7 syn-eruptive (in the lead up, during or in the immediate aftermath of volcanic eruption) earthquakes in the North Taupō Fault Zone since the emplacement of Karapiti tephra (Unit B), that can be temporally linked to volcanic eruptions from Taupō volcano. In TK2, primary pumice from the Opepe tephra infills a ~30 cm-wide fissure formed in the post-Ōruanui loess, providing evidence of intense ground-shaking contemporaneously with the emplacement of the Opepe tephra. Evidence of syn-eruptive fault movements was also observed in association with the emplacement of the Waimihia and Whakaipō tephras (Wilson, 1993).

Of all the eruptions from Taupō, the 232 CE eruption shows the greatest number of interactions with the North Taupō Fault Zone, where there is evidence in TK2, TK3, TK4, TK5, DBRC1 and TKRC1 of at least three syn-eruptive earthquake events occurring prior to, during, and in the aftermath of the eruption. These events affected both the Whakaipō and Kaiapo faults, demonstrating persistent fault activity on multiple fault stands of the North Taupō Fault Zone during the 232 CE eruption sequence. Fault displacements and/or ground shaking in the lead up to the 232 CE eruption sequence were observed in TK2, TK3, TK4, DB1, DBRC1 and TKRC1. For example, in TK2, a steep paleoscarp is blanketed by an early fall deposit of the 232 CE eruption sequence, the Rotongaio ash, necessitating that this ash was emplaced before the free face could erode significantly (i.e., days to months) (e.g., Gold et al., 2026). Evidence of fault activity during the onset and immediately before Taupō ignimbrite emplacement is found in TK2, TK3, TK4 and TKRC1. For example, in TK2 and TKRC1, the Rotongaio ash is displaced and buried by the initial products of the Taupō ignimbrite (Subunit Y6-L1), preserving an upright scarp. In DB1, reworked beds of Taupō ignimbrite were slumped onto the valley floor from valley walls during emplacement of the co-ignimbrite ash. Given both the rapid deposition of these layers and lack of evidence for water reworking, we infer that there was intense ground shaking in the hours-long time period immediately after ignimbrite emplacement in order to drive this slumping of material from higher topography in the valley. Finally, analysis of paleoshorelines at Whakaipō Bay presented in Gold et al. (2026) support upwards of 10 m of fault displacements on Whakaipō Fault in the ~20-year aftermath period of the Taupō eruption, possibly related to a protracted phase of caldera collapse.

In all, our results demonstrate strong volcano-tectonic coupling at Taupō volcano, where eruptions and earthquakes are often interdependent and function within an integrated system. Whether this syn-eruptive faulting is a cause or consequence of volcanic activity remains uncertain; however it must be considered possible that eruptions at Taupō volcano have the potential to be triggered by fault ruptures in the North Taupō Fault Zone. Hazard assessments of the volcano must therefore incorporate earthquake models when considering triggers for volcanic unrest and eruption. Furthermore, traditional models for forecasting earthquake hazard probabilities based on recurrence intervals may be insufficient to accurately constrain the hazards posed by these faults, supporting a multi-hazard framework for Taupō volcano.

Whakapapa-Based Framing of Te Taiao and Multi-Hazard Systems

A whakapapa-based understanding of te taiao provides a relational framework for interpreting environmental processes and hazard interactions. Within this worldview, the natural world is not composed of discrete or independent systems but is instead organised through genealogical relationships originating from Ranginui and Papatūānuku (Marsden & Henare, 1992; Royal 1998). Domains such as the ocean (Tangaroa), and atmospheric processes (Tāwhirimātea) are therefore understood as genealogically related, rather than functionally separate (Mead, 2016).

This relational ontology offers a complementary basis for understanding what are commonly described within hazard science as ‘multi-hazard’ or ‘cascading’ events, where hazard processes are conceptualised as interacting, triggering, or compounding system dynamics (Gill & Malamud, 2014; Kappes et al., 2012), which a whakapapa-based framing interprets as expressions of relationships within a shared genealogical system. Rather than viewing hazards as discrete phenomena that interact externally, a whakapapa-based framing understands these interactions as expressions of relationships within a shared genealogical system. Such an approach aligns with Indigenous systems thinking, where environmental processes are understood as interconnected and co-evolving (Durie,1998; Harmsworth & Awatere, 2013). In this way, interactions between atmospheric, hydrological, and geomorphological processes can be interpreted not only as system linkages, but as interconnected responses within a relational system.

Importantly, this framing also repositions human communities within these dynamics. As descendants within the same genealogical system, human actions are not external drivers acting upon the environment but are part of the relational network that shapes environmental outcomes. Risk, therefore, can be understood not only in terms of exposure and vulnerability, but also as a manifestation of imbalance or misalignment within these relationships, consistent with principles of kaitiakitanga and relational responsibility (Harmsworth et al., 2002; Mead, 2016; Roberts et al.,1995).

Our demonstration that volcanic, tectonic, and surface processes operate as an interconnected system aligns strongly with a whakapapa-based understanding of te taiao. Future work should consider further integration of a whakapapa-based understanding of te taiao into multi-hazard research at Taupō, which offers an opportunity to move beyond reductionist and siloed approaches toward a more holistic, systems-oriented understanding of risk. This has relevance for natural hazard assessment, and resilience planning in Aotearoa, where place-based, relational approaches can complement and strengthen existing scientific models (Harmsworth & Awatere, 2013; Hikuroa, 2017).

Conclusions

Our team has conducted field and paleoseismic analyses along major normal faults of the North Taupō Fault Zone to examine their earthquake histories and how fault activity is associated with eruptions from Taupō volcano. Our analyses reveal eight earthquake events on both the Kaiapo and Whakaipō Faults since eruption of the Karapiti volcanic layer at 11.8 ka, supporting a maximum earthquake recurrence of 1,475 yrs, with an associated vertical slip rate on the Kaiapo Fault of 1.67 mm/yr. Furthermore, we identify syn-eruptive faulting during 4 eruptions from Taupō volcano, with the 232 CE eruption demonstrating the greatest number of interactions with the North Taupō Fault Zone. Our results demonstrate strong volcano-tectonic coupling, supporting a multi-hazard framework for Taupō volcano.

Research benefits and future directions

By supporting two postgraduate students from the University of Auckland, this project has increased capacity in earthquake and volcanic hazards research in Aotearoa. Our research provides constraints on the maximum recurrence intervals (1,475 years) of major faults of the North Taupō Fault Zone (Kaiapo and Whakaipō Faults), which will be incorporated in the New Zealand Active Fault Database and future editions of the National Seismic Hazard Model. We also show that some large eruptions from Taupō may be preceded by episodes of fault rupture. Our demonstration of strong volcano-tectonic coupling at Taupō volcano highlights the need for future research that will improve our understanding of, and capacity to respond to, multi-hazard scenarios at Taupō volcano, particularly when considering scenarios of heightened volcanic unrest.

Publications and research outputs

Output Type*	Date Published/ Completed	Author/s	Title	DOI or Link
Journal Article	January 2026	AS Gold, M Snowden, JD Muirhead, P Villamor, G Coffey, C Wilson, R Morgenstern	Large-scale rift-related faulting linked to a caldera-forming eruption: A case study from Taupō, New Zealand	[10.1016/j.jvolgeores.2025.108481](https://doi.org/10.1016/j.jvolgeores.2025.108481)
Hochstetter Lecture Tour	March-May 2026	P Villamor	Do New Zealand's active faults and volcanoes talk to each other? Insights from 25 years of trenching ancient faults	https://gsnz.org.nz/news-and-events/geoscience-lecture/
Conference Presentation	May 2026	J Muirhead, A Gold, M Snowden, P Villamor, C Wilson, G Coffey, R Morgenstern	Large-scale rift-related faulting linked to a caldera-forming eruption: A case study from Taupō, New Zealand	European Geophysical Union Conference
Conference Presentation	February 2026	J Muirhead, A Gold, M Snowden, P Villamor, C Wilson, G Coffey, R Morgenstern	Paleoshoreline displacements at Lake Taupō record exceptional normal fault offsets in the Hochstetter Lecture Tour aftermath of the 232 CE Taupō eruption	11th IAG Conference on Geomorphology
Conference Presentation	February 2026	A Gold, J Muirhead, P Villamor, G Coffey, C Wilson, K Gilchrist, J Williams	Determining fault-slip histories in challenging regions of extensive tephra accumulation in the Taupō Volcanic Zone	11th IAG Conference on Geomorphology
Conference Presentation	November 2025	A Gold, James Muirhead, P Villamor, G Coffey, C	History of faulting and the twin threat of seismic and volcanic hazards near Taupō Volcano	Geoscience Society of New Zealand Conference

		Wilson, K Gilchrist, E Turinimana, J Williams		

Communications and dissemination

Radio New Zealand article on the team's paleoseismic trenches in April 2025: https://www.rnz.co.nz/news/national/557670/earthquakes-and-eruptions-studying-the-twin-threat-on-the-taupo-fault-belt

Natural Hazards Commission/Toka Tū Ake web article on our investigation into the history of earthquakes at Taupō: https://www.naturalhazards.govt.nz/news/new-research-digs-into-25500-year-history-of-taupo-supervolcano-to-unearth-insights-into-the-regions-twin-threats/

Article in The Post, on our investigation into the history of earthquakes at Taupō: https://www.thepost.co.nz/nz-news/360649695/taupos-supervolcano-explored-links-earthquakes

One News piece on our trenching work in December 2025

https://www.1news.co.nz/2026/01/06/how-the-twin-threats-of-taupo-could-help-predict-future-disasters/

Research team

James Muirhead: University of Auckland, Project Lead contributing to field logistics, data collection and analysis, student supervision, publications, connecting with stakeholders, and communications/outreach.

Pilar Villamor: Earth Sciences New Zealand, Associate Investigator contributing to field logistics, data collection and analysis, student supervision, publications, connecting with stakeholders, and communications/outreach.

Colin Wilson: Victoria University of Wellington, Associate Investigator with experience of Taupō volcano geology, contributing to field logistics, data collection and analysis, student supervision, and publications.

Genevieve Coffey: Earth Sciences New Zealand, Research Collaborator contributing to data collection and analysis, and publications.

Student details

Name:	Alexander Gold	**Status:**	Active
Institution:	University of Auckland	**Primary Supervisor:**	James Muirhead
Start Date:	July 2024	**End Date:**	July 2027
Degree Type:	PhD	**NHC Funded:**	Partially
Project Title:	Rifted arc evolution from the perspective of volcano-tectonic interactions and fault slip histories associated with the large volume rhyolitic volcanism of the Taupō Volcanic Zone		

Name:	Tegan Peglar	**Status:**	Active
Institution:	University of Auckland	**Primary Supervisor:**	James Muirhead
Start Date:	March 2026	**End Date:**	November 2026
Degree Type:	Hons	**NHC Funded:**	Partially
Project Title:	A history of faulting on the Whakaipō Fault		

References

Barker, S.J., Wilson, C.J.N., Illsley-Kemp, F., Leonard, G.S., Mestel, E.R.H., Mauriohooho, K., Charlier, B.L.A., 2021. Taupō: An overview of New Zealand's youngest supervolcano. New Zealand Journal of Geology and Geophysics 64, 320–346. https://doi.org/10.1080/00288306.2020.1792515

Durie, M., 1998. Te Mana, Te Kāwanatanga: The politics of Māori Self-Determination. Oxford University Press.

Gill, J.C., Malamud, B.D., 2014, Reviewing and visualizing the interactions of natural hazards. Reviews of Geophysics, 52(4), 680-722.

Harmsworth, G., Awatere, S., 2013, Indigenous Māori knowledge and perspectives of ecosystems. Ecosystem Services, 2, 1-7.

Harmsworth, G., Barclay-Kerr, K., Reedy, T., 2002, Māori sustainable development in the 21st century: The importance of Māori values, strategic planning and information systems. He Puna Korero: Journal of Maori and Pacific Development, 3(2), 40-68.

Hikuroa, D., 2017, Mātauranga Māori-the ūkaipō of knowledge in New Zealand. Journal of the Royal Society of New Zealand, 47(1), 5-10.

Kappes, M.S., Keiler, M., von Elverfeldt, K., Glade, T., 2012, Challenges of analysing multi-hazard risk: A review. Natural Hazards, 64(2), 1925-1958.

Gold, A.S., Snowden, M., Muirhead, J.D., Villamor, P., Coffey, G.L., Wilson, C.J.N., Morgenstern, R., 2026. Large-scale rift-related faulting linked to a caldera-forming eruption: A case study from Taupō, New Zealand. Journal of Volcanology and Geothermal Research 469, 108481. https://doi.org/10.1016/j.jvolgeores.2025.108481

Marsden, M., Henae, T.A., 1992, Kaitiakitanga: A definitive introduction to the holistic worldview of the Māori. Ministry for the Environment.

Mead, H.M., 2016, Tikanga Māori: Living by Māori Values (Revised ed.). Huia Publishers.

Morgenstern, R., Litchfield, N.J., Langridge, R.M., Heron, D.W., Townsend, D.B., Villamor, P., Barrell, D.J.A., Ries, W.F., Van Dissen, R.J., Clark, K.J., Coffey, G.L., Zoeller, A., Howell, A., Easterbrook-Clarke, L.H., 2024. New Zealand Active Faults Database: the high-resolution dataset v2.0. New Zealand Journal of Geology and Geophysics 68, 955-970. https://doi.org/10.1080/00288306.2024.2427396

Muirhead, J.D., Illsley-Kemp, F., Barker, S.J., Villamor, P., Wilson, C.J.N., Otway, P., Mestel, E.R.H., Leonard, G.S., Ellis, S., Savage, M.K., Bannister, S., Rowland, J.V., Townsend, D., Hamling, I.J., Hreinsdóttir, S., Smith, B., McGregor, R., Snowden, M., Shalla, Y., 2022. Stretching, shaking, inflating: volcanic-tectonic interactions at a rifting silicic caldera. Frontiers in Earth Science 10, 835841. https://doi.org/10.3389/feart.2022.835841

Plattner, A.M., 2020. GPRPy: Open-source ground-penetrating radar processing and visualization software. The Leading Edge 39, 332–337. https://doi.org/10.1190/tle39050332.1

Roberts, M., Norman, W., Minhinnick, N., Wihongi, D., Kirkwood, C., 1995, Kaitiakitanga: Māori perspectives on conservation. Pacific Conservation Biology, 2(1), 7-20.

Royal, T.A.C., 1998, Te Ao Mārama: A Research Paradigm. He Pukenga Kōrero, 4(1), 1-8.

Toitū Te Whenua – Land Information New Zealand, 2025. New Zealand 1 m Digital Elevation Model (DEM) Hillshade [Dataset]. LINZ Data Service. https://data.linz.govt.nz/layer/121859-new-zealand-lidar-1m-dem/

Vandergoes, M.J., Hogg, A.G., Lowe, D.J., Newnham, R.M., Denton, G.H., Southon, J., Barrell, D.J.A., Wilson, C.J.N., McGlone, M.S., Allan, A.S.R., Almond, P.C., Petchey, F., Dabell, K., Dieffenbacher-Krall, A.C., Blaauw, M., 2013. A revised age for the Kawakawa/Oruanui tephra, a key marker for the Last Glacial Maximum in New Zealand. Quaternary Science Reviews 74, 195–201. https://doi.org/10.1016/j.quascirev.2012.11.006

Villamor, P., Berryman, K., Nairn, I.A., Wilson, K., Litchfield, N., Ries, W., 2011. Associations between volcanic eruptions from Okataina volcanic center and surface rupture of nearby active faults, Taupo rift, New Zealand: Insights into the nature of volcano-tectonic interactions. Geological Society of America Bulletin 123, 1383–1405. https://doi.org/10.1130/B30184.1

Wilson, C.J.N., 1993. Stratigraphy, chronology, styles and dynamics of late Quaternary eruptions from Taupo volcano, New Zealand. Philosophical Transactions of the Royal Society of London A343, 205–306. https://doi.org/10.1098/rsta.1993.0050