

Review of: “*Distributed right-lateral strain at the northern boundary of the Quito-Latacunga microblock*” by Harrichhausen et al., submitted to Solid Earth

Reviewer: Dr Sam Wimpenny (University of Bristol, UK)

Overview

This manuscript presents new geomorphological and satellite remote-sensing observations of active faulting from the Inter-Andean Valley between Ecuador and Colombia. The authors use these new observations to test whether the distribution of strain inferred from the recently published block models of Jarrin et al., [2023] matches the kinematics and distribution of active faulting. They identify five new active faults across a ~70 km wide zone, which all lie north of an inferred block boundary. The authors also use paleoseismological trenching and Quaternary dating methods to determine the recent history of major earthquakes along two faults.

The manuscript is well-presented, with good quality figures and clear writing. I found it interesting to read and am sure others with specific interest in the tectonics and seismic hazard in the Northern Andes will find it a useful contribution to the literature.

I have some minor comments for the authors to consider before publication, but otherwise **I recommend the article can be published after minor corrections.**

General Comments

Consider emphasising the poor constraints of the block model boundary from the GNSS velocities: The Jarrin et al., [2013] block model boundary is constrained by three GNSS velocity measurements in the study region from what I can tell, and the model itself is not consistent with the velocities within uncertainty. The position of the block boundary is therefore poorly constrained. I would recommend highlighting this to motivate the manuscript, as where shear strain is being accommodated is poorly known. I say this because the argument that the authors make around finding the active faulting to be more distributed than predicted by the block model is expected – strain fields are almost always accommodated by multiple faults within continental lithosphere, particularly within mountain belts [McKenzie 1978].

Interpretation of distributed deformation in the InSAR data: I would recommend more clarity regarding what is meant by “distributed deformation” in Section 5.1. Some people use “distributed” to mean inelastic off-fault deformation [e.g. Milliner et al., 2025]. Here it is being used to mean any displacement around the fault that is not related to slip that reaches the surface. Such deformation can still reflect the elastic response of the wall rock to slip on parts of the fault buried at depth. Therefore, it is not necessarily converted into permanent deformation that would be visible in the geomorphological or geological record of the region (e.g. surface ruptures, subsidiary faults).

Consider adding some reflection on how precise the radiocarbon dates are given they are based on bulk sampling: The authors should consider: (1) describing what organic material they think they were dating within the bulk radiocarbon samples, and (2) reflecting on what the true uncertainties may be on these stratigraphic dates that

are not captured by the formal lab-based uncertainties. Many studies assume a (conservative) ~1 kyr age uncertainty from bulk sampling because of the effects of bioturbation and root penetration meaning that organic matter does become mixed throughout the stratigraphy [e.g. Grutzner et al., 2016]. This mixing effect can explain why lots of trench sections have some ages that are out of stratigraphic order (just as the authors find in their trench and which they discount). However, the same processes will also affect other stratigraphic age estimates based on bulk sampling, even if it does not cause them to become out of stratigraphic order.

Line-by-Line Comments

Line 28: Grammatical error "...whether deformation it is focused or...."

Line 30: "Shear zones..." are particular structural geological structures in my eye – maybe consider rephrasing to "further characterise the distribution of faulting that accommodates deformation in the upper crust"?

Line 46: No comma in "with the recent rupture, reveals..."

Line 48: Comma missing from "...faults lie within the proposed epicentral area, and could be responsible for, the 1868 M 6.8 ..."

Line 48: Not sure this sentence makes sense to me: "By placing this study in context with ..." – the study *is* the context as far as I can tell.

Line 50: Would be worth stating quantitatively here what you consider "wide zone" to be? Is that 20 km or 200 km?

Figure 1: Figure caption says "strain rates from Jarrin..." but you're showing slip rates across block boundaries and not strain rates.

Line 71: Grammatical error "...faults along strike to the north-east that transverse..."

Line 78: Consider rephrasing to: "...show 0.7-1.6 mm/yr and 1.1-2.6 mm/yr of right-lateral reverse slip across the Buesaco and Aranda Faults, respectively."

Line 81: Consider rephrasing to "A southward decrease in the eastward component of the GNSS velocities across the northern boundary consistent with right-lateral shear strain on ENE-WSW striking planes predicted ..." – more precise about the velocity gradients and relation to inferred strain field.

Line 88: Worth being explicit that you're saying that the GNSS velocities with ~20 km of Chiles may capture transient volcanic deformation rather than velocities that are representative of the long-term tectonic deformation. As written, it could sound like *all* GNSS velocities may reflect volcanic deformation.

Line 92: Consider rephrasing "... Colombia provides higher spatial resolution measurements of deformation across the norther ..."

Line 94-95: You would only expect sharp velocity gradients across faults creeping near the surface or where there had been recent earthquakes. A gradient in the velocity over ~20 km is entirely consistent with there being elastic strain accumulation around a single fault which is locked in the top ~15-20 km of the crust [e.g. Wright et al., 2001], so could well be representative of a block boundary.

Line 98: Should be “analysis” not “analyses” as it’s singular.

Line 105-107 and Figure 2: I would recommend providing the hypocentral locations of earthquakes alongside with the focal mechanisms of the larger events ($M_w > 5$) in Figure 2 if there are any. The focal mechanisms are key information as well for how the present-day strain field is being accommodated by faulting.

Line 115-119: Worth emphasising somehow that the earthquake was triggered, but that the total amount of strain generated by the episode of volcanic inflation was too small to account for the amplitude of fault slip. Therefore, there is probably tectonic strain accumulation in this area too, not just faulting entirely driven by magmatism. This means that the mechanism of the event should be related to the wider tectonic setting, rather than the local strain field caused by volcanic inflation/diking.

Section 3: Do you need this section? The information about Quaternary glaciation and landscape is important for understanding the sediments within which scarps are preserved, but could come in the Intro or section on fault-related geomorphology. The bedrock geology component seems overly detailed to me and the reader gets a little distracted here. I understand that later you compare the trends of the active faults with those within the bedrock geology, but that can simply be stated with citations later.

Line 171: Cite the filtering approach – has someone else tested this carefully? If it’s new here, then it needs explaining in more detail. What type of filter are you using?

Line 172: Explain what unwrapping method you used? Did you not bother unwrapping the Sentinel-1 interferograms (why not)?

Line 185: Missing bracket closure around link.

Line 193-194: Were you specifically projecting the lateral moraine crests?

He-3 Cosmogenic Dating: Is sample erosion a factor in influencing the exposure age (this is not mentioned)? Do the authors account for this in the uncertainties on the estimated dates, or do they assume negligible erosion? Is there field evidence that supports this assumption?

Line 266: How many kilometres wide?

Line 273-274: Strikes should be quoted in 3 figures (060-070) as they’re azimuths.

Line 292: Spelling error “...and then displaces the stream along ...”

Line 297: Correct grammar of this sentence: “Additionally, the undulating terrain relatively minor vertical ...”

Section 5.3: Looking at the terrain topography, have you tried creating structure contours for the fault to constrain its dip? It looks like it should be near vertical by the way it cross-cuts the topography in Figure 5b, but it is a simple exercise and would add evidence to support the inference that the faults are likely mostly strike-slip.

Figure 6 & 7 order: Figure 6 is only briefly mentioned before an extensive discussion of the observations in Figure 7 – consider switching the order in which these appear in the text so the reader doesn't jump backwards and forwards between figures.

Line 309: Should be “WSW-ENE-striking fault zone” based on Figure 5.

Line 311: Spelling “...narrows to a single strand...”

Line 338: Avoid starting sentence with “~” – just use the word “Approximately”.

Line 348: Grammar “... the the...”

Line 366: “Assume it is recycled” – more specifically you assume that the colluvial wedge contains sources of organic matter that are recycled and have been transported into a fracture. Could make this clearer in the text.

Section 6.2: It is unclear to me whether volcanic deformation would cause accelerated strike-slip faulting over the long term (i.e. ~10 kyrs) because it would require the strain from volcanic deformation be translated predominantly into permanent right-lateral strain on ENE-WSW trending planes. Volcanic deformation related to magma intrusions (dykes, sills, spherical magma reservoirs) induces dominantly vertical displacements [Okada et al., 1985; Yang et al., 1998], and therefore dominantly dip-slip faulting [Rubin 1998]. Consider reflecting on whether this mechanism is mechanically feasible and consistent with the (absence of) evidence of dip-slip faulting.

Line 470: Change “don't” to “do not”.

References

Wright, T., Parsons, B. and Fielding, E., 2001. Measurement of interseismic strain accumulation across the North Anatolian Fault by satellite radar interferometry. *Geophysical Research Letters*, 28(10), pp.2117-2120.

Grützner, C., Schneiderwind, S., Papanikolaou, I., Deligiannakis, G., Pallikarakis, A. and Reicherter, K., 2016. New constraints on extensional tectonics and seismic hazard in northern Attica, Greece: the case of the Miliesi Fault. *Geophysical Journal International*, 204(1), pp.180-199.

Milliner, C., Avouac, J.P., Dolan, J.F. and Hollingsworth, J., 2025. Localization of inelastic strain with fault maturity and effects on earthquake characteristics. *Nature Geoscience*, pp.1-8.

McKenzie, D., 1978. Active tectonics of the Alpine—Himalayan belt: the Aegean Sea and surrounding regions. *Geophysical Journal International*, 55(1), pp.217-254.