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Interactive comment on "Seismic hazard in low slip rate crustal faults, estimating the characteristic event and the most hazardous zone: study case San Ramón fault, in central Andes" *by* Nicolás P. Estay et al.

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This paper discusses the problem of fault segmentation along the San Ramón fault system at the west flank of the Andes, and associated seismic hazard for the city of Santiago.

The paper presents observations on subsurface structure from geophysics, seismic activity and expected PGA values from modeling results, in the case of single segment rupture scenarios. In that sense, results shown in this work support the active character of the fault and its capability to produce large earthquakes and strong ground motion

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Discussion paper

as previously published (Armijo et al., 2010; Vargas et al., 2014; Pérez et al., 2014). The paper provides new observations at subsurface from TEM analysis in a specific sector along the fault, in a similar sense to what is shown in Díaz et al. (2014).

Authors provide really interesting evidences from gravimetry profiles, supporting that this fault system is segmented, like initially stated by Armijo et al. (2010) and then in deep demonstrated in the PhD thesis of Rauld (2011), from the analysis of well preserved fault scarps. In fact, fault segments that authors show are really consistent with those defined in previous work. In this sense, would be interesting to clarify and discuss the novel contribution on this matter (segmentation) with respect to previous results.

The major point of this work is the discussion about the possibility that fault segments are tectonically disconnected, producing earthquakes only limited to 10 km of rupture length, discarding the possibility for an earthquake rupture along the entire-recognized fault length (ca. 25-30 km) like inferred and discussed in the previous work already cited.

My major concern is some apparently contradiction between what the authors show as evidences and what they can conclude, appearing –to me- as a confusion between fault segmentation and possibilities for large earthquake ruptures. Authors conclude that the fault is segmented, and because of that discard the possibility for an entire rupture connecting different segments between at least the Maipo and Mapocho rivers, as previously proposed (Armijo et al., 2010; Rauld, 2011; Vargas et al., 2014). For example they conclude: “Geophysical and geomorphological evidences suggest that the SRF is segmented into 4 sub-faults that most likely are activated independently. Under this scenario a characteristic earthquake of magnitude Mw = 6.2 – 6.7 is expected.” However, previously the same authors state “Although we cannot ruled out a single rupture of the whole FSR segments, our evidences consistently favor the occurrence of a single segment characteristic earthquake, with a rupture length of $\sim$ 10 km.” I think this is a major point that can produce confusion especially for people do not familiarized with this specific subject, but more importantly, needs to be more properly argued and discussed in the optic of geologic information as well as historic and past ruptures.

How can you explain a ca. 5 m of slip at surface along the fault, deduced from direct observations in trenches (Vargas et al., 2014), with only a single 10 km length segment rupture scenario? Please discuss in terms of scale relationship and provide some examples; in the work of Wells and Coppersmith (1994, which you already cited), it looks that slip in the order of 5 m (at surface, it can be more -in average or maximum- at depth) are mostly associated to earthquake rupture magnitude in the order of 7 or greater, and not in the order of Mw6.2-6.6 as finally deduced in this work in the case of the corresponding segment 3 (Figure 9). On the contrary, many examples can be cited for surface ruptures along reverse faults connecting different fault segments -some of them partly blind- during large earthquakes (eg. see McCalpin, 2009; Chapter 5; see Nabelek, 1985, in the case of the Mw7.3 El Asnam earthquake).

Finally, I think this paper shows really interesting and novel results supporting the segmentation of this fault system and providing model results for the case of single segment rupture scenarios, which is –itself- an important contribution. But the worse case scenario that authors proposes, assuming only a single segment rupture (Mw6.2-6.7), is apparently inconsistent with field observations shown and discussed in previous work, and needs to be better argued. This is a major point taking the emphasis and implications for natural hazard assessment of Santiago city.

Specific comments:

1. Considering the seismic network you installed, please clarify: What's the threshold-magnitude? Were all the stations triggered by each of the events you found? What instruments did you use, broadband, short period, LHZ? What's the depth in boreholes for the installation of seismic stations? Can you provide moment tensor-solutions for the seismic events that you associated to the fault? It could be interesting a more developed discussion of your findings by comparing methodologies and results with

those explained in the previous work of Pérez et al. (2014; Natural Hazards); in this last article, authors did a precise location of small events under seismic stations surveyed during ten years, providing moment tensors for those finally associated to the SRF.

2. It's not clear if PGA estimations consider or not near-field effects, directivity and stochastic kinematics. Stochastic faulting models are important to predict PGA values. It would be interesting to discuss your findings in the sense of Herrero & Bernard (1994), Lavalle and Archuleta (2003), or even the PAGER from USGS, which suggest the possibility of the different variables to induce errors and artifacts on PGA model results. Please also discuss your methodologies and findings in the optic of previous results for this specific case, already published by Pérez et al. (2014; Natural Hazards).

3. Results from gravimetry are really interesting, I think this is a major contribution for this case of study (SRF). Fault segments can be in partly covered or blind and subsurface geophysics can provides useful indirect observations to complement those made at surface, contributing to unravel the faults. However, it's an exaggeration to state: "Basement morphology is a useful marker of cumulative faulting. Since SRF has a low slip rate, fault scarp morphology may be modified by deposit and/or erosion surface processes. Thus, we favour the use of gravity profiles and geomorphological measurements instead of scarp topographic analyses." If you insist, please develop –argue- more in deep this idea that contradicts decades of advancements in paleoseismology and earthquake geology (eg. McCalpin, 2009).

Specifically, how can you interpret slip from these profiles? I don't understand what are the arguments and assumptions supporting slip inferences, please clarify (specifically for the age and then kinematics). The thickness of the sedimentary cover inferred from gravimetry profiles is really small near the fault; It's possible to discard the influence of previous erosional and depositional processes (transit basin) from the adjacent quebradas, and then the influence on the interpretation of inherited basement morphology, fault segmentation and cumulative slip?

Profiles 22 and 24 show a similar basement shape close to the fault than profiles located more to the north. . . Why it's possible to interpret "no slip"? (Figure 6).

4. The contribution of the application of morphometric indexes (SL and SI) is unclear to me. What are the limitations for this kind of analysis in this specific case? For example, could -the indexes you used- have been influenced by landslide deposits present in the area? (Armijo et al. 2010; Rauld, 2011). . . and by the Maipo and Mapocho rivers in the areas close to?

5. In Figure 4, please show a map for the location of these profiles. The TEM profile appears over-interpreted. Can you provide more arguments/evidences to interpret all the faults shown in Figure 4b? or at least discuss the limits of this interpretation, eg. see Díaz et al. (2014) for the relationship between direct observations at surface and indirect measurements at subsurface from this same fault system. Figure 4c; please, provide more clear evidences for the presence of the fault, may be a more detailed mapping of the photo. . . It's really difficult to see/deduce any fault present there.

6. We probably need to be more careful with the use of "characteristic earthquake". Earthquakes are known to be complex phenomena –even more at crustal scale- and self-organized (Bak et al. 1981, Burridge and Knoppoff 1964). Of course, the most hazardous zone would be defined by the high frequency contain of the earthquake.

7. To compare potential effects of an earthquake along the SRF with those observed during the 2010 Mw8.8 Maule subduction earthquake it's valid, but it would be better to explore also other crustal earthquakes with similar magnitude. It could be interesting to the paper if you can make some comparison with the 1958 Mw 6.9 Las Melosas earthquake (close to Santiago), and with the 1995 Mw 7.0 Kobe Earthquake. Even better, I think the comparison with the Northridge and El Asnam earthquakes are probably nice opportunities to discuss your results. The 1980 Mw7.3 El Asnam earthquake produced a 24 km length rupture along a segmented thrust fault, in partly blind, which generated 3-6.5 m of slip at surface (Nabelek, 1985). The 1994 Mw6.7 Northridge earthquake

was associated to a blind fault-rupture which resulted from 3 meters of reverse slip on a 15-kilometer thrust fault that raised the Santa Susana mountains 70 centimeters at surface, generating strong ground motion, with PGA close to 0.9g in some places (USGS, Science, 1994).

8. Minor comments: -Line 9 &10: Reference is needed for both earthquakes. -Line 20: Please, precise Andersonian regime... Compression in E-W direction? -Title and introduction: Please, can you provide a –tectonic- reference to support that the SRF is located in the "central Andes"? -Since the paper show results from the application of many different geophysical methods, I would recommend to provide some basic concepts at the beginning of each section. -Figures 1 and 3, please cite Armijo et al. (2010) to properly refers or mapping the San Ramón Fault.

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