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eEarth Discussions



# *Interactive comment on* "Characteristics of chlorites in seismogenic fault zones: the Taiwan Chelungpu Fault Drilling Project (TCDP) core sample" *by* Y. Hashimoto et al.

**Y. Hashimoto et al.**

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Major changes Characteristics of chlorites in seismogenic fault zones: the Taiwan Chelungpu Fault Drilling Project (TCDP) core sample Hashimoto et al.

I appreciate the reviewer for many constructive comments and suggestions. I will describe major modifications in our manuscript in the following.

1. The reviewer suggested that the evidences of the radical reaction should be described in more detail.

I put sentences about this as "The pH of fluid can be changed by a radical reaction, which is an interaction between a surface that has been newly formed by fracturing and



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Discussion Paper

water (Kameda, et al., 2003; Saruwatari et al., 2004). The gouge and breccia must be originated form the host rock of the Chinsui shale. The fractal distribution of the grain size in gouge suggested that the gouge is formed by brittle fracturing (Ma et al., 2006). It is difficult, however, to apply the experimental result of radical reaction to a natural example quantitatively because of the complexity of the mineral composition (Saruwatari et al., 2004)." in the lower part of Discussion section. As reviewer suggested, Ma et al. (2006) provides the good evidence that the brittle fracturing must occur to form gouges and breccias from host rocks.

2. The reviewer suggested that the comparison between boreholes A and B should be described.

I put the sentence about that as "In the borehole A which is located at 40m apart from the borehole B, three fault zones were also observed as FZA 1111, FZA 1222 and FZA 1253 (e.g., Ma et al., 2006). Those fault zones must be corresponding to the fault zones in borehole B." in the occurrence senction.

3. The reviewer suggested that EPMA is helpful to crosscheck the iron and magnesium content in chlorite estimated from the XRD chart.

As I mentioned the eED reply, I agree with this suggestion. But it is difficult to do that because the samples are very limited. In addition to the reason, it is also difficult to make good polished thin section from the clay gouge to analyze the iron content in chlorite by EMPA, I think. So, I did not conduct EPMA although I agree with the suggestion.

4. The reviewer pointed out that Ohta and Yajima (1988) is not appropriate to refer because it is hard to get the paper. In addition, he introduced another paper which should be referred to describe the relationship between temperature and iron content in chlorite.

I agree with the reviewers comment. Although I still think that Ohta and Yajime (1988)



eED
2, S107–S114, 2007

is a good reference because they described directly on the relationship, the introduced paper is also useful to refer. Therefore, I added a sentence as "Similarly, Vidal et al. (2006) also reported that the high iron content in chlorite at a higher temperature condition from the regional metamorphic belt although the condition of reaction can differ from the fault zones." in lower discussion section.

5. The reviewer suggested that the discussion about the location of the fault zone related to the Chi-Chi earthquake referring earlier studies for boreholes A and B in TCDP.

This manuscript focuses on chlorite within the host rocks and fault rocks. The chlorite was not formed only from the Chi-Chi earthquake but also from some historical earthquakes in seismic cycles. Therefore, I think that it is not critical to discuss about the location of the fault zone related to the Chi-Chi earthquake. Of course, the issue is very significant and interested to understand the mechanisms of earthquake from natural materials in some cases for example to discuss about the thermal heating. This manuscript could not provide some evidences to discuss about that. So, I did not put the discussion in this manuscript. Instead, I added sentences as "The fault rocks analyzed in this study must be formed by historical earthquake cycles. So, the characteristics of chlorite might contain the historical processes." in the end of occurrences of fault zones section.

6. The reviewer suggested that it is better to conduct the qualitative analysis of clay mineral contents.

I agree with the reviewers comment. The analysis provides some evidences about the reaction along the seismogenic fault and gives more interest to wider readers. As I described in the eED comments, however, the qualitative analysis of clay mineral contents is conducted by another researcher in our group. He must prepare the manuscript about the issue. So I could not describe about that. Please understand our situations.

Technical comments Almost all the technical comments are fixed as the reviewer



eED

2, S107–S114, 2007

pointed out and suggested.

- page 87 line 3: precise (TCDP, borehole B)

Fixed

- page 87 line 10: The hydroxide and silicate layers of chlorite

Fixed

- page 87 line 15-18: "Therefore, on the basis of chlorite characteristics, the reactions at the seismogenic fault are due not only to the thermal decomposition resulting from the temperature rise but also to rock-ﬂuid interactions".

Fixed

- Page 87 line 24: "mechanical processes and reactions" (because there is probably several mechanical processes and reactions resulting in the presence of clays within fault rocks and because both are strongly linked, Vrolijk and van der Pluijm, 1999)

Fixed

- page 88 line 9: thrust instead of thurst

Fixed

- page 88 line 21: seismicity instead of seismisity

Fixed

- page 88 line 24-25: "We use chlorite to examine the mechanisms of clay mineral formation along seismogenic fault." Chlorite will help to precise the thermal and chemical conditions within the fault zones related to ear thquakes rather than to decipher the formation (neocr ystallization?) of clays during seismic events.

We modified the sentence as "We use chlorite to examine the issue because characteristics of chlorite can provide thermal and chemical conditions along the fault."



eED

2, S107–S114, 2007

- page 89 line 6: shales instead of shale, "composed of black shales"

Fixed

- Page 89 line 2: "we identiﬁed three fault zones". The passive form would be more appropriate: "three fault zones have been identiﬁed" because there is several already published papers dealing with core samples from TCDP holes A and B (Ma et al. 2006, Nature; Hirono et al. 2007, JGR, 2006a and 2006b GRL amongst others).

Fixed

- Page 89 line 20-21, 25 and 26-27: "The fractured-damaged zone (up to 1.2 m) is located outside the breccia zone (Fig. 2)." Not clear. Replace by something like: "Two fracture-damaged zones are located above and below each breccia zone" or "on both sides of the fault zone" or "constitute the outer par ts of the fault zone".

We modified the sentence as "Two fractured-damaged zones (up to 1.2 m) are located above and below each breccia zone (Fig. 2)."

- Page 90 line 5: "using 1.4 mm grains". Do you mean "using $<$1.4 mm grain-sized fraction after crushing and sieving"?

Fixed

- Page 90 lines 8-9: show also the peaks for smectite, illite and kaolinite on figure 3.

Fixed

- Page 90 line 16: how can you tell the polytype (clinochlore-1MIIb) from XRD on oriented samples?

We also conducted XRD analysis for random oriented samples. We put the sentence about that in the method section and the part as pointed out above.

- Page 90 line 18: "Although the oriented samples" replace by "Although oriented sam-



eED

2, S107–S114, 2007

ples".

Fixed

- Page 90 lines 31-33: there is an inversion for calculation of parameters. I(003)/I(005) gives the symetr y of Fe distribution (D value in Moore and Reynolds, p. 213) and (I(002) + I(004)/I(003)') gives the number of Fe atoms in six octahedral sites (Y value in Moore and Reynolds, p. 214).

Fixed

- Page 90 lines 48-21: the sentence is too long and the syntax is incorrect (number of verbs). Replace by something like: " We have estimated the iron and magnesium contents in chlorite from XRD char ts following the method proposed by Moore and Reynolds (1989)". These authors use also oriented samples for clay mineral determination but procedure proposed by Brown and Brindley (1980, in Moore and Reynolds, 1989) has been calculated for random orientation of crystallites.

Fixed

- Page 91 line 1: the equation (1) is from Brown and Brindley (1980, cited in Moore and Reynolds, 1989).

Fixed

- Page 92 line 2: as the reference Ohta and Yajima (1988) is not easily available, the authors should say explicitly if iron content increases or decreases with increasing temperature.

This part is the first sentence in Discussion section. I describe the factors to control the iron content in chlorite generally in this part. I describe the relationship between temperature and amount of iron in chlorite later in detail.

- Page 92 line 4: "can control" instead of "can be control".



eED

2, S107–S114, 2007

Fixed

- Page 92 lines 5-8: "In this study, however, the source materials of Chinsui shale is enough homogeneous and could not control the low value of iron content. This might be suppor ted by that the iron and magnesium contents in host rocks are enough constant as represented in Fig. 4." This is in apparent contradiction with what is written in the previous page on line 17-18. I suggest to replace this sentence by: "However, the Chinsui shale is ver y homogeneous as shown by the constant iron and magnesium contents in host rocks (Fig. 4). Therefore, the source material also was probably homogeneous and is not the cause of the low value of iron content in the gouge."

Fixed

- Page 92 line 9-11: Be concise: A thermal anomaly has been repor ted on the basis of borehole logging in TCDP borehole A at the FZA 1111 fault which corresponds to FZB 1136 in borehole B.

Fixed

- Page 92 line 16-18: Mishima et al. (2006) have worked on FZB 1194 and FZB 1243 fault rocks and not on FZB 1136.

Fixed

- Page 92 line 1: give again the reference for pH of ﬂuid controlling the iron content in chlorite (Ross, 1969; Malmstrom et al. 1996).

Fixed

- Page 93 line 8: "where magnetite or maghemite is supposed to have formed (Mishima et al. 2006)"

Fixed

- page 94 line 28: Sibson instead of Shibson



eED

2, S107–S114, 2007

Fixed

- Page 95 ﬁgure 1: Shuagtung fault: the name is not visible on the pattern for Miocene rocks. This pattern appears different on the ﬁgure and in the legend.

Fixed

- Page 96 caption: precise "distributions of I(003)/I(005) (indicative of the symetr y of Fe distribution, gray circles) and (I(002) + I(004)/I(003)' (indicative of the total number of Fe atoms, black triangles)"

Fixed

- Page 97 ﬁgure 3: show also the peaks for smectite, illite and kaolinite

Fixed

- Page 98 figure 4: put a ver tical light line for I(003)/I(005) = 3.83 which corresponds to the symetr y zero (Fe = Mg in the two sites). This is more explicite for reader who are not familiar with the XRD Moore and Reynolds method.

The symmetrical line is not vertical in my calculations by NEWMOD. I put the symmetrical line in the figure.

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Interactive comment on eEarth Discuss., 2, 85, 2007.