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Hydrology and Earth System Sciences
Discussions

Interactive comment on "Groundwater flow processes and mixing in active volcanic systems: the case of Guadalajara (Mexico)" *by* A. Hernández-Antonio et al.

A. Hernández-Antonio et al.

jurgen@itesm.mx

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Dear Dr. Custodio,

thank you very much for your additional comments. Our answers are added below each of your review comments:

#1. 3H analyses are not inexpensive when electrolytic concentration is needed.

A: 3H analysis (including enrichment) cost typically 200 USD per sample at a commercial basis and with a turnaround time of more or less 2 months. We think that radioactive tracers like 14C and 3H are now relatively accessible in comparison to ear-

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lier times due to the availability of a large number of competitive labs worldwide. As an alternative, the use of numerical flow models would be more expensive and these are based on hydraulic information.

#2. The accuracy of data is not given and this is important. The average accuracy of tritium analyses was ∼0.3 TU. Groundwater values varied between 0.4 and 2.1 TU.

#3. Since 18O and 2H are highly correlated, one of them can be excluded from the statistical analysis o better 2H can be substitutes by excess deuterium to enhance the small differences in Fig 6 caption how and altitude has been given to the samples should be given to be able to understand properly the plot; it seems that some altitude effect is present but looks too high.

A: This information is complemented in section 4.2. Figure 6 shows the graphical 18O and deuterium excess was added.

4.2 Isotope hydrology The ïĄď2H vs. ïĄď18O graph shows that the analyzed groundwater is of meteoric origin with variable evaporation and mixed with hydrothermal fluid (Fig. 6a). Data reported by IMTA (1992), GEOEX (2004) and this study show groundwater evolution (Fig 6a). Although, all studies show a similar trend, the data reported by IMTA (1992) registered heavier ïĄď18O values that may be attributable to evaporation or hydrothermal influence. Similar ïĄď18O values in thermal systems have been reported in other studies, e.g. El-Fiky (2009) and Stumpp et al. (2014) with ïĄď18O values ranging from -6.7 to -5.6 ‰ and -4.8 to +0.8 ‰ respectively. Water from Group 1 (hydrothermal influenced) collected in Toluquilla, has a narrow range of ïĄď18O (-9.4 to -8.8‰ and ïĄď2H (-67 to -68‰ values. They tend to fall slightly below and parallel to the RMWL, possibly indicating different climate conditions during recharge. These samples show isotopic depletion, indicating that recharge by meteoric water is low, as demonstrated by a deuterium excess that ranges from 4 to 8 ‰ with an average of 5.5 ‰ (Fig. 6b). On the other hand, it is possible that only a displacement of ïĄď18O is occurring, which could correspond to a geothermal effect and mixing with meteoric

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waters (Giggenbach and Lyon, 1977; Herrera and Custodio, 2003). The increased Cl concentrations compared to other groups evidences mixture with hydrothermal fluids and longer residence time (Fig. 6c). Group 2 waters, collected in the eastern and southern part of the ATAS, have ïĄď18O values ranging from -9.6 to -8.6‰ and ïĄď2H values from -63 to -71‰Ṫhese waters fall along the RMWL. Deuterium excess values vary between 5.3 and 8.1 ‰ with an average of 6.7 ‰Ṫhese values are similar to other groups (Fig. 6b), therefore, in accordance with the low concentration of Cl, groundwater recharge is of meteoric origin (Fig. 6c). Group 3 waters (influenced by anthropogenic pollution) are quite different from the rest; they have heavier ïĄď18O values ranging from -7.9 to -5.7‰ and ïĄď2H values varying from -59.6 to -47.5‰ and are strongly affected by evaporation. Also a lower deuterium excess in the order of +4‰ is observed (Fig. 6b y 6c). The enriched outlier AT12 represents groundwater from a recreational park with lagoons. In this well there is a negative deuterium excess indicating that rainwater presented evaporative diffusion processes in the soil during recharge process (Custodio, 1997; Manzano et al., 2001). Group 4 waters, mostly from La Primavera recharge area, are covering a relative wide range of values compared to group 1 and 2. Their ïĄď18O signatures vary from -10.3 to -8.4‰ and their ïĄď2H signatures from -72.2‰ to -63.9‰Ḋeuterium excess in these wells are the highest and indicate preferential recharge during certain times of the year (Jiménez-Martínez y Custodio, 2008). The overlapping of group 1, 2 and 4 indicates that aquifer formations are mostly hydraulically interconnected. Although altitude variations are in the order of only 400 m around La Primavera caldera, this seems to be enough to generate an altitude effect (Fig 6d).

Figure 6: (a) Deuterium and oxygen-18 in groundwater from the ATAS using this and previous studies. Note: GMWL = Global Meteoric Water Line (Rozanski et al., 1993), RMWL = Regional Meteoric Water Line (Wassenaar et al., 2009); (b) oxygen-18 vs. deuterium excess with labelled altitudes; (c) oxygen-18 vs. chloride concentration; and (d) oxygen-18 vs. altitude.

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#4. The calcedonia geothermometer does not point to the type of rock (basalt, andesite) as said in pp13 If possible fig 8 will improve introducing some more geological data instead of only rock classification

A: this observation was also addressed in the comment 1 referring to the hydrogeological section. Fig. 8 was replaced with a new Fig. 3 as mentioned in the previous comments. In addition, pp.13 in Section 4.4 was changes.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 12, 1599, 2015.

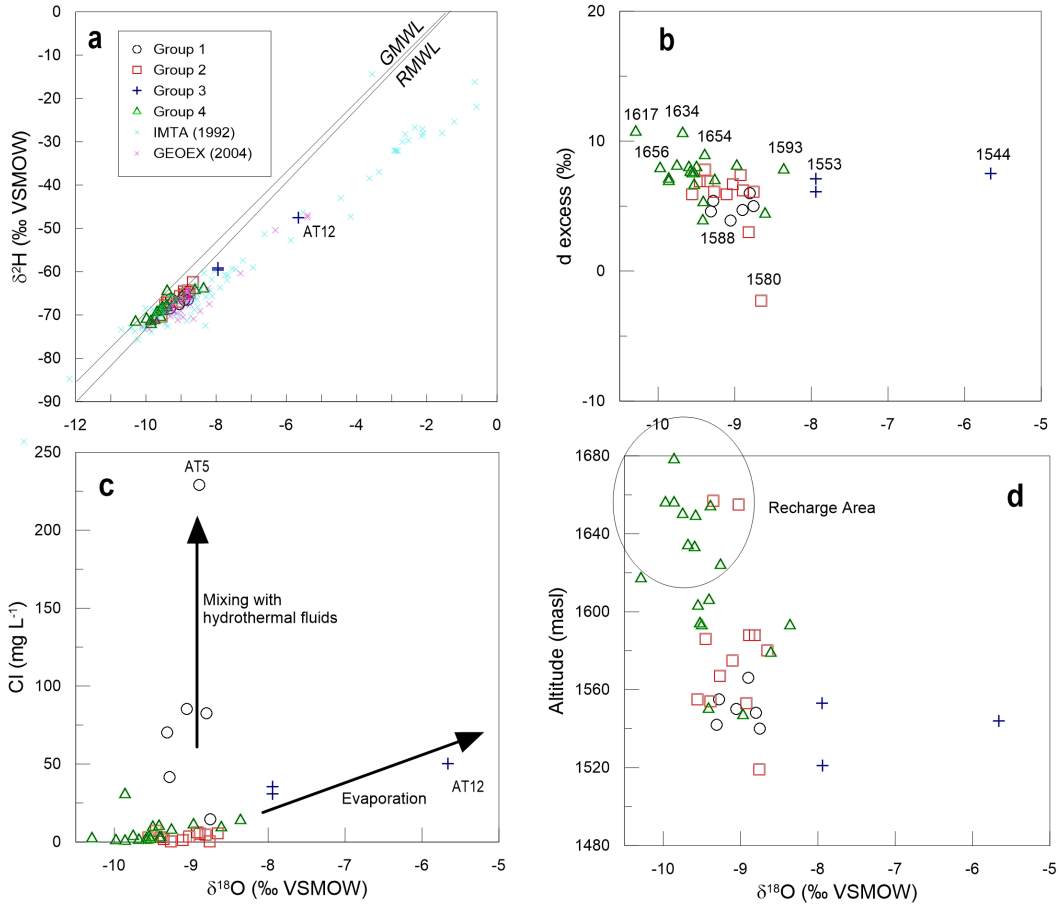

Fig. 1. Figure 6: (a) Deuterium and oxygen-18 in groundwater from the ATAS using this and previous studies. Note: GMWL = Global Meteoric Water Line (Rozanski et al., 1993), RMWL = Regional Meteoric Water Line