General Comments:

The authors of this paper put forward the novel suggestion that the absence or presence of hydrocarbons at typical reservoir depths in fold and thrust belts may be used to infer whether the faults beneath the folds are able to generate large earthquakes or not. The mechanism that they propose is that earthquakes with M > 5.5 produce shaking that fractures the reservoir seals, allowing hydrocarbons to leak to the surface, resulting in sterile fields. This is an interesting conjecture, relevant to Natural Hazards and Earth Systems, and bringing it forward for discussion is good.

Their suggestion is developed in the context of the 2012 Emilia-Romagna earthquake sequence, a sequence of great contemporary interest. However, because of the slow rate of convergence (1 – 3 mm/yr) across the region, the expected recurrence interval for earthquakes on the relevant structures is very long, with only 4 M > 5.5 earthquakes having occurred over the past five centuries. Of these, only the two events in 2012 were located instrumentally, with fault rupture areas relatively well constrained. By limiting their study to this region, the authors are forced to deal with a poor statistical sample.

The authors make clear that the structures beneath areas that generate large earthquakes and earthquakes that may not are similar, with folds overlying deeper thrusts in both cases. Since development of these structures is associated with large motions on faults, it would be interesting, but not essential, to discuss why, with comparable materials and geology, some faults slip in earthquakes and others could slip aseismically.

Specific Comments

My major specific comment is that the statistical treatment in support of the novel suggestion is not very convincing. To acquire the data used to try to test the hypothesis that earthquakes result in sterile reservoirs, the authors use a large, publically available data base about hydrocarbon (oil and gas) wells. They group the wells into three categories: a) positively sterile; b) positively productive, and c) wells that encountered oil or gas that either was not produced or was produced from shallow depths – called "ambiguous."

From the standpoint of the main suggestion of the paper – that earthquakes cause reservoirs to leak, the lack of a clear explanation of why wells in category c) should be separated into a separate category from b) and given such a subjective name as "ambiguous" is a concern. It seems to me that the question of whether when oil or gas is present it is produced or not is not related to whether the reservoir leaks – if the hydrocarbon is there, it seems that the reservoir has not leaked. I do not understand why category c) data are excluded from the statistical test. However, since the locations of the historical ISS are somewhat uncertain, and including the

category c) data would mainly affect the conclusions about the 1624 ISS, I do not think that including category c) data would completely refute the suggestion.

Another problem with the statistical analysis is that, in my opinion, the application of binomial test is not appropriate. The binomial test is based on the assumption that the distribution being tested is random. It could be argued that the distribution of category a) wells is approximately random. However, category b) wells are clearly clustered in space, as can be seen in Figure 1. The reason for this clustering is that new wells are preferentially drilled close to producing wells – once a sweet spot is found, it is highly likely that adjacent areas will also be productive. One way around this problem would be to divide the region into equal area blocks. That is, test the area containing producing wells, not the number of wells. The area might be chosen to be comparable to the source area of a M = 5, or, alternatively, with a characteristic dimension comparable to the average well spacing .

In addition, limiting the area tested to the interior of the rectangle defining each ISS seems problematic. The largest ground shaking tends to be near the edges of the fault patch, but not confined to its interior.

Although almost all of the paper is devoted to investigations of both oil and gas reservoirs, and most of these, including Cavone, produce far more oil than gas, the paper ends with the conclusion that only depleted gas reservoirs, not depleted oil reservoirs, should be used for underground gas storage. Whether this recommendation is true or not, it does not seem to have support in the preceding text of the paper. Similarly, the specification of "gas reservoirs" in the title is misleading because the bulk of the analysis involves oil reservoirs.

As noted above, because the rate of occurrence of earthquakes in the region investigated is relatively low, the statistics is quite challenging. Perhaps publication of this paper will stimulate further investigation in other regions with more earthquakes. Along those lines, McGarr (BSSA, 1991) examined three earthquakes that occurred beneath producing oil fields (Coalinga 1983, Kettleman N. Dome 1985, Whittier Narrows 1987). So there seems to be evidence that, at least in California, earthquakes and reservoirs coincide.

In the abstract, it seems misleading to say that the 2012 earthquake source regions were "surrounded" by productive wells. Figure 1 shows almost a complete 180° arc north of the mainshock epicenter with no producing wells, as well as a smaller but substantial gap to the south.

Technical comments:

Figure 1 caption – the description of the 1624 earthquake has typos ". . . and 1624, and 19 March. . ."