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Solid Earth Discussions

Interactive comment on "Correlation between tectonic stress regimes and methane seepage on the west-Svalbard margin" *by* Andreia Plaza-Faverola and Marie Keiding

Anonymous Referee #2

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General comments. The paper investigates the relationships between tectonic stress generated by spreading along the Molloy and the Knipovich oceanic ridges and the presence of active and extinct seepage along the Vestensa ridge, offshore western Svalbard. The tectonic stresses has been modeled assuming dislocation in an infinite elastic space (Okada's model). The authors find a good correlation between the areal distribution of tensile stress and the occurrence of active seepage, whereas the extinct seeps invariably fall within areas characterized by a strike-slip regime. However, as the authors correctly acknowledge, there is a good but not exact correspondence between active seepage and tensile stress distribution. This analysis has taken into account exclusively the tectonic forces, an approach that has been criticized by Reviewer 1, who

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has called upon the role of glacial rebound. In my opinion, the study area is located near active structures, and the contribution of tectonic stress may be worth of investigation. However, there are some important issues that need to be addressed more carefully, as detailed below in the Specific comments. In particular, the description of the structural setting of the Vestensa ridge and the geometrical relationships between the active stress field and the orientation of faults should be more stringent. On the whole, the manuscript is clearly laid out, and has the potential to appeal to a general international audience.

Specific comments. 1. Structural setting of the Vestensa ridge. The structural setting of Vestensa ridge is of crucial importance for understanding active and relict seepage that has localized on this structure. However, description of structural geology is sloppy in many points. To start with, the manuscript misses a discussion regarding the possible genetic relationships between the Vestensa ridge and the Molloy/Knipovich oceanic ridges and their associated transform faults. In addition, origin, age and tectonic structure of the Vestensa ridge have not been discussed. The seismic section illustrated in figure 2 shows the geometry of a gentle anticline. I assume that this anticline corresponds to the Vestensa ridge, yet no location of this seismic section is reported. In addition, the Vestensa ridge shows a marked variation of its trend, with its western sector trending NW and the eastern sector oriented ca. NNW. Does this variation correspond to a difference in structural controls? Panel (b) of Figure 1 should be expanded conveniently to illustrate the location of active and extinct seeps, together with the trace of faults and the anticline axis shown in Figure 2. This would help the reader to visualize better the structural setting of the study area.

2. Fold activity. As far as I can tell, the 'Vestensa' anticline deforms post-1.5 Ma Pleistocene sediments. A central point thus regards the establishment of whether the fold is still active or not. This point may be important in that anticlines are the preferential locus of active seepage because they trap the raising fluids at the fold core. Outer arc (extrados) normal faults may thus provide efficient fluid pathways. Many of the faults

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dipping toward the fold core (sketched on Figure 2seismic section) could belong to this category. The amplification of this fold would thus be accommodated by the formation of new faults and/or the opening of existing ones. This possibility could be relevant in case this fold has been controlling active seepage. Again, this calls upon the requirement for a better definition of the structural setting of the Vestensa ridge (point above).

3. Geometric relationships between stress field and pre-existing faults. A interesting point suggested by the modelling results is that existing normal faults could be opened by the operating tensile stress. Normal faults experience sealing-opening cycles that are typically dictated by fluid pressure pulses. On the other hand, this behavior is also controlled by the geometric relationships between the orientation of stress axes and the pre-existing structures. One can note in Figure 3 that active seepage occurs along a NW-trend, whereas inactive seeps occur along a ca. E-W trend. I wonder whether active seepage is depending upon the geometrical relationships between the orientation of regional stress field and the trend of faults. The distinction between active and relict seepage is essentially based on the assumption that a tensile stress regime favors seepage whereas a strike-slip one would not. This reasoning may be not invariably true because strike-slip faults are often steep and connect the subsurface reservoir to the surface, thereby representing efficient fluid pathways. As a matter of fact, there are many examples worldwide where active seepage focuses on both inactive and active strike-slip faults, as well as extensional jogs forming along strike-slip fault systems. In this regard, the manuscript should discuss more deeply why seepage along faults that fall into areas with strike-slip regime is discouraged. Is it because the maximum horizontal stress SH is sub-orthogonal to fault trend? In case the maximum horizontal stress SH is favorably oriented for reactivation, faulting would instead favor fluid upraising. This point could be resolved by showing the orientation of SH and/or Sh axes throughout the study area, together with fault traces on the Vestensa ridge.

4. Earthquake-induced seepage. It is assumed that (line 61) ‘Our study is in line

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with observations of earthquake-induced seafloor seepage'. However, it should be noted that seepage and/or paroxysmal activity is not necessarily linked to earthquakes, but generally result from the 'normal' evolution of the system. Earthquakes represent obvious external forcing that may occasionally interfere with the system.

Technical corrections. Title of section GEOLOGICAL SETTING OF THE VESTNESA RIDGE SEEPAGE SYSTEM (lines 65) should be numbered as 2 rather than 1. Numbering of following sections should be changed accordingly.

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