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Interactive comment on "Extrusion dynamics of deep-water volcanoes" *by* Qiliang Sun et al.

Qiliang Sun et al.

sunqiliang@cug.edu.cn

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Dear Dr. William W. Chadwick,

We thank for your very useful comments and the positive assessment of our work. The detailed responses to your comments are listed bellows:

Comment 1: Line 1: I think a better title for this paper would be something like "3D seismic imaging of Miocene volcanoes in the South China Sea" – something that is more informative to the reader about the real content of the paper. I don't think this paper is a general discussion about "extrusion dynamics of deep-water volcanoes".

Response 1: Considering a lot of contents were referred to the extrusion dynamics of deep-water volcanoes (See the detailed Responses 2, 4 and 7) and we used 3D seismic data in this paper, we changed the title to "Extrusion dynamics of deep-water vol-

canoes revealed by 3D seismic data" to make this title more informative to the reader.

Comment 2: Line 17 and throughout: What does "extrusion dynamics" mean here and throughout the manuscript? The authors need to explain what this means to them somewhere early in the paper. How can 3D (static) seismic images tell you about "dynamics"?

Response 2: Here, 'extrusion dynamics' means how the erupted materials flow and accumulate. Yes, the seismic images are 'static' in the sense volcanism has long-since ceased. However, the present structure and distribution of the volcanoes and their lavas allow us to infer how they formed (i.e. their "dynamics").

Comment 3: Lines 24-25: I suggest taking out "shallow sub-surface depths" because it is unnecessary and potentially confusing with the "deep-water" emplacement of the volcano as a whole. (water depths vs. subsurface depths within sediment)

Response 3: We have deleted "shallow sub-surface depths" from the revised manuscript.

Comment 4: Line 26: In my experience high hydrostatic pressure has little effect on eruption processes (1000 m vs 4000 m depth), so I'm skeptical about this sentence.

Response 4: This has been modified in the revised manuscript (Lines 25-28: Extrusion dynamics were likely controlled by low magma viscosities as a result of increased dissolved H2O due to high hydrostatic pressure, and soft, near-seabed sediments, which collectively are characteristic of deep-water environments). We attribute the long run out of the lava flows due to increased effusion rate and low lava viscosity. The control of hydrostatic pressure in this setting is on the solubility of the erupted melt, where up to (and over) 20 MPa of hydrostatic pressure may allow lavas to be very H2O-rich, with viscosities up to an order of magnitude lower than their subaerial counterparts and/or submarine lavas erupted in drier tectonic settings (e.g. at Axial seamount). This is detailed more within the discussion (Lines 336-339).

Comment 5: Line 49: It seems to me a distinction should be made here. With before-and-after bathymetric surveys, the volumes of individual eruptions CAN be well-constrained. It is only if you don't have information on the pre-existing topography or bathymetry – or you are estimating over longer periods of time (multiple eruptions or an entire volcano's history) that volume estimation is more difficult.

Response 5: Yes, we agree with you that the volumes of individual eruptions can be relatively well-constrained, if we carry out the before- and –after-eruption bathymetric surveys and meanwhile less erosion occurs at the basal surface. We have expressed this meaning in the sentence "By collecting high-resolution, quantitative data on the morphology of modern volcanic edifices and surrounding lava flows from airborne/shuttle radar topography or time-lapse multi-beam bathymetry, we can estimate erupted volumes, at least for individual eruptive episodes (e.g. Holcomb et al., 1988; Walker, 1993; Goto and McPhie, 2004; Cocchi et al., 2016; Somoza et al., 2017; Allen et al., 2018; Chadwick et al., 2018; Grosse and Kervyn, 2018)" (Lines 41-46). In fact, a pseudo three-dimensional data with only the upper and lower surfaces has been made, if the before- and –after-eruption bathymetric data are available. This pseudo three-dimensional data can use it to characterize the distribution of erupted material and calculate the volume. However, it cannot image the internal or basal structures of the erupted materials, and thus cannot establish how volcanoes grow and lava is emplaced over multiple eruptive episodes. Moreover, if large-scale erosion occurs at the basal surface of lava flow, the volume estimate only based on the before- and –after-eruption bathymetric surveys will be incorrect. Therefore, we still need 'full 3D structure of these extrusive systems' to 'assess the accuracy of estimated volumes of total erupted materials, or test volcano growths and lava emplacement models'. Because we have expressed similar meaning as the reviewer suggested in the sentence mentioned above, we only made a minor revision to this sentence (added 'total'; Line 49) to highlight the volume represents that of entire volcano's history.

Comment 6: Line 51-58: The authors should mention these papers on seismic imag-

ing of Axial Seamount (an active basaltic caldera with a summit depth of ∼1400 m): Arnulf, A. F., A. J. Harding, G. M. Kent, S. M. Carbotte, J. P. Canales, and M. R. Nedimovic (2014), Anatomy of an active submarine volcano, Geology, 42(8), 655-658, doi:10.1130/G35629.1. Arnulf, A. F., A. J. Harding, G. M. Kent, and W. S. D. Wilcock (2018), Structure, seismicity, and accretionary processes at the hotspot-influenced Axial Seamount on the Juan de Fuca Ridge, J. Geophys. Res., 123, doi:10.1029/2017JB015131.

Response 6: We have read and cited Arnulf et al. (2014). However, Arnulf et al. (2018) focuses on a tomographic inversion of OBS data, and although 2D multi-channel seismic data are used, it is quite different from these we mention in Lines 51-58. We therefore choose not to cite Arnulf et al. (2018).

Comment 7: Line 68: Why would pressure have an effect on rheology? Observations from are recent eruption site at ∼4000 m depth in the Mariana back-arc suggest that high hydrostatic pressure there had little or no effect on eruption dynamics and lava morphology, compared to submarine eruptions observed at shallower depths (for example Axial Seamount at ∼1500 m): Chadwick, W. W., Jr., S. G. Merle, E. T. Baker, S. L. Walker, J. A. Resing, D. A. Butterfield, M. O. Anderson, T. Baumberger, and A. M. Bobbitt (2018), A recent volcanic eruption discovered on the central Mariana back-arc spreading center, Front. Ear. Sci., 6:172, doi:10.3389/feart.2018.00172.

Response 7: As addressed in a previous comment (Response 4), the greater hydrostatic pressure will also control the solubility of H2O in melt at the point of eruption (e.g. >20 MPa). Increased H2O content in melt may lower bulk lava viscosity enough to modulate effusion rate and propagation dynamics. Dissolved H2O content in magma will depend on the continental setting, so we may not expect H2O-controlled viscosity effects to be as observable in tectonic settings where H2O-undersaturated (even dry) magmas are being erupted on the seafloor e.g. mid ocean ridges and back arc basins. We have modified this sentence to: "We suggest the high hydrostatic pressure of the deep-water environment controlled melt H2O content and internal lava viscosity, effusion rate and, consequently, volcano and lava flow morphology and run-out distance" (Lines 73-75).

Comment 8: Line 71: This statement is inaccurate. Before-and-after multibeam bathymetry calculates depth changes from the shape of the pre-eruption seafloor to the post-eruption seafloor, so does NOT assume a smooth base. You should re-phrase this to something like: "Any eruption volume estimates that do not include pre-eruption topography may be grossly underestimated."

Response 8: We have revised this sentence; "Our results also show that erupted volumes calculated from airborne/shuttle radar topography or time-lapse multi-beam bathymetry data, without knowledge of detailed geometry of the basal surfaces of the lava flows and the volcanoes themselves, may be grossly underestimated, particularly if extrusion was explosive and/or involved erosion of the seabed" (Lines 76-79).

Comment 9: Line 331: I question whether any of the referenced papers here support the statement that "extensive lava flows in deep water... occur primarily because of high hydrostatic pressure...". In fact, I question that conclusion at all.

Response 9: We have revised this sentence. The sentence now reads; "Extensive lava flows have also been observed at other deep-water volcanoes (e.g. Chadwick et al., 2018; Embley and Rubin, 2018; Ikegami et al., 2018) where greater dissolved H2O contents in melt imply lower melt viscosity while the lavas were mobile." (Lines 336-338). See also response to comment 7. A detailed geochemical analyses of samples would be required to test this hypothesis; unfortunately this is not within the scope of the present study.

Comment 10: Line 344: You need to explain why you interpret that there are lava tubes (vs. just channels).

Response 10: In this study, the lava tube is core channel or channelization. In the plan view, it looks like a channel with high-low sinuosity. Therefore, we are apt to call them

as 'lava flow channel' in this study.

Comment 11: Line 385-386: These references do not support this statement (in the 2nd half of the sentence). The Caress et al. paper describes an eruption in which the largest volume was erupted after lateral intrusion (not transport on the surface), and the Carey et al paper describes an eruption for which the largest volume was erupted as a pumice raft that floated to the ocean surface.

Response 11: Here we simply consider the ratio between the volume of erupted materials contained within the main volcano edifice vs. volume of lava flows transported from the volcano edifice; we do not consider how the erupted materials are transported. To avoid confusion, we have deleted the latter part of this sentence.

Comment 12: Figure 1: If the contour lines are in ms what do they show? The twt to the seafloor? Or some sub-surface horizon? Why not just use depth contours?

Response 12: Figure 1b is the bathymetry of the study area and the contours are in ms (twt). Our 3D seismic data are in a time- rather than depth domain, thus all maps and profiles are presented in time domain. A precise velocity model is needed to convert from time to depth.

Comment 13: Figure 5: "Lava" is misspelled in the figure 5b legend.

Response 13: We have revised Figure 5b.

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