This paper is potentially an excellent contribution to the experimental literature on natural, complex, multi-component, volcanic rocks. Initially, the authors provide an excellent treatment of the relevant rheological behavior of high-temperature deformation in glassy samples which is followed by a good characterization of representative, pre-experiment cores. The study comprises a substantial number of experiments both at ambient room (20°C) and magmatic temperatures (900°C). The rheological data is of high quality and the experimental conditions and span a reasonable range of deformation rates and timescales. The authors do an excellent job of presenting the results separately from analysis and a thorough job of explaining the major decisions and assumptions they had to make in the process of running the experiments (i.e., how and why samples were chosen based on porosity, connected porosity, etc., detail on how experimental charges were loaded and the effect that has on the experiment). The rheological analysis is solid and prima facie, the interpretations seem sound and lead to a number of logical conclusions about the behavior of these multicomponent systems under conditions relevant to Unzen eruptions.

We thank the reviewer, Steve Quane, for his concise summary and descriptive comments which are answered below.

However, I see one main oversight in their otherwise detailed and robust analysis; there are no descriptions, photos, or representative images and quantitative measurements (porosity, density) of experimental run products. This is a major issue for several reasons:

a) Deformation in experimental charges cannot be interpreted by using the rheological data alone. For example, seemingly "viscous" behavior and "brittle" behavior were interpreted (starting is section 4.1) based on the "mechanical responses" of the rocks. The authors make assumptions and "attributions" about the actual mechanical behavior of the samples with no empirical evidence. For example, they "attribute to a narrowing of pre-existing cracks" and "hypothesize may reflect a contribution of viscous deformation upon loading". It is possible that these interpretations are correct, however, it would be relatively easy to test the attributions and hypotheses by halting an experiment at the requisite place on the deformation path and doing microstructural analysis.

We thank the reviewer for bringing this point to our attention. With reference to the high temperature viscous responses we refer the reviewer to work by Cordonnier et al., (2012), referenced in the text, who look, in detail, at the mechanical response curves of deformed samples and label them 'viscous', 'transitional' and 'brittle' according to X-ray microcomputed tomography scans of deformed samples. We particularly refer to Figures 1 and 2 in Cordonnier et al., (2012) – as such we are not defining new regimes but simply categorising our samples according to regimes already defined. With reference to the brittle experiments, we refer the reviewer to publications mentioned in the text (Hoek and Bieniawski, 1965; e.g. Brace et al., 1966; Scholz, 1968; Heap et al., 2014) *who describe, in detail, the four stages of mechanical loading and brittle failure with reference to the mechanical stress-strain curves. Although the authors agree that 'halting an experiment at the requisite place on the deformation path and doing microstructural analysis' would be a very informative study, this work has already previously been tackled, stress-strain curves have been dissected with respect to sample attributes, and for brittle experiments, the regimes of crack-closure, elastic deformation, strain hardening, and failure are well defined and identifiable by the mechanical curves. Therefore, we reassure the reviewer that care has been taken when labelling a response as 'viscous' or 'brittle' by referring to previous work in rock and lava deformation, based on their stress-strain curves.*

That said, we understand the need to examine the experimental run products and have taken the reviewers concerns on board. We have illustrated our examination of the experimental products acquired by SEM imaging to create a new Figure 5, along with further descriptions and photographs of samples after deformation to Figure 12 (previously Figure 10). This analysis, based on the reviewers' comments made us revisit our labelling of samples, and we have issued a new comprehensive, visual description of failure, as seen in Figure 12. We also further concluded that the state of 'transitional' can be further sub-divided to clearly express that it is a spectrum leading from viscous behaviour, indicated from a continuous plateau in stress with substantial strain, to brittle behaviour, defined by a

sharp drop in stress with little strain beyond an initial elastic loading response. Therefore, we suggest that a sample can either be in the viscous dominated regime while undergoing a transitional behaviour, where the stress plateaus with strain but there are small stress drops along the way, or the brittle dominated regime where the stress-drop is poorly defined and 'curves' before reaching high strain at failure (Figure 5; Figure 11). Although the post deformation photographs and SEM images are a useful guide, as the same strains before experiment termination/sample failure were not met by every sample (we chose our end strains based on characteristics of the stress-strain curves not on a set total strain) the results are not entirely comparable e.g. a viscous sample experiment would be terminated at much shorter strains (than a transitional sample) as its curve was already defining viscous behaviour. Thus, we consider the stress-strain curves a better method for quantitatively of defining the deformation mode of lavas.

b) Post experiment analysis of end products can lead to surprising conclusions about mechanical behavior. In these multicomponent systems, deformation can occur via several mechanisms. Bubble collapse, brittle fracturing, viscous flow of groundmass glass, microcracking, rotation of grains, grain boundary sliding, internal grain deformation. All of these are factors in accommodating strain in the samples. Hence, strain can be accommodated homogenously (throughout the sample evenly) or it can be localized into bands or disparate parts of the sample. Without post experiment analysis, these important rheological behaviors cannot be determined. The authors are making the most logical conclusions about their "brittle" and "viscous" determinations based on the rheological data, however, without visual analysis of bulk properties and microstructures, the authors cannot confirm behavior. In addition, they are losing a considerable amount of important information about the nature of the deformation.

We thank the reviewer for his comments and agree, understanding the complex mechanisms that led to failure in volcanic rocks is important, yet, here, this paper is not trying to decipher the deformation mechanism (e.g., viscous, plastic, brittle) but the deformation mode of lavas (i.e, ductile vs brittle) necessary to constrain (and distinguish between) flow and fragmentation processes. [Please note that the distinction between the two is that of scale: a deformation mode refers to the macroscopic character of sample deformation whereas a deformation mechanism refers to microscopic deformation processes. Thus, unfortunately in this field of laboratory testing, brittle may be used when refereeing to both a deformation mode (sample failure) and a deformation mechanism (i.e., a cracking event); see also Rutter in Tectonophysics (1986) *and Heap et al. in Bull. Volc.* (2015) *for clarity] We have conducted further analysis of the experimental products as described above. We also guide the reviewer to Figure 2 in Lavallee et al., (2007) where post-experiment textures have been viewed and deformation mechanisms discussed, and to Figure 2 in Kendrick et al., (2013), as well as Figure 2 in Kendrick et al., (2017), where textural evolution with strain is depicted and the deformation mechanisms are interpreted. Appreciating the need for a more in-depth explanation of the overarching deformation mechanisms in the deformation mode discussed (e.g. 'brittle' and 'viscous' and offer the reviewer the new Figure 12 (previously Figure 10) with accompanying edits in the manuscript. A detailed study of the exact microstructural deformation mechanisms at play across all samples is beyond the scope of this paper seeking to constrain deformation mode (not mechanism), and as it has already previously been discussed in other studies, we chose to highlight samples representative of each regime and map the textures associated with the different deformation regimes and link these to the stress-strain curve characteristics used to define the remaining samples.*

c) Post experiment analysis of physical properties (i.e., density, porosity) can yield important information on the nature of deformation. Certainly, for the cores that were not destroyed during brittle failure, the authors can make density and porosity determinations via the methods they used on the pre-experiment cores. Bulging of cores may cause a little consternation, however, established methods exist in the volcanology literature to measure density and porosity on irregular samples.

We advise the reviewer that samples that remained completely intact (only those with a completely 'viscous' response, i.e. those carried out at strain rates of 10^{-5} s^{-1}) were re-measured to constrain

changes in connected porosity. However, the results showed no significant change in porosity, nor in the volume of the sample determined by pycnometry (Table 1); hence, we mention this in the text but do not present the data in the study. Due to minor loss of volume from the experimental process (removal of sample from pistons etc.) the pycnometer readings are within error and thus we concluded, cannot be considered.

Table 1. Example of volume measurements made using pycnometery on samples that remained intact after deformation. Fractional change in volume is < ± 0.05% of the measured volume

Sample	*Initial porosity*	*Strain rate tested (s^{-1})*	*Temperature tested (°C)*	*Measured volume before (cm^3)*	*Measured volume after (cm^3)*	*Fractional change in measured volume*
UNZ-4-16	*0.12*	*1.00E-05*	*900*	*12.17*	*12.14*	*0.003*
UNZ-4-17	*0.12*	*1.00E-05*	*900*	*11.67*	*11.72*	*-0.005*
UNZ-8-16	*0.18*	*1.00E-05*	*900*	*11.38*	*11.32*	*0.005*

d) Characterizing the amount of strain in the samples is an independent measure of machine strain. Does the sample show the same amount of strain as the machine? This can be determined through post-experiment analysis of density, porosity and core geometry. It is an important check on the experimental apparatus to ensure all strain from the machine is going into the sample. Quane and Russell, 2005 (cited by authors) and Quane et al., 2004 from American Mineralogist go through these procedures in detail.
We refer the reviewer to the first paragraph in section 2.3. of the manuscript: '[Note: all mechanical data have been corrected for the compliance of the setup, quantified via Instron procedures that monitor length changes due to loading of the pistons in contact with one another]'. This compliance method is carried out at all temperatures tested in our laboratory. Following the application of the compliance correction, the total strain referred to in the manuscript is the sample strain and not machine strain. Post-deformation sample geometry (i.e. final sample length, for the in-tact samples) was measured for the samples to confirm final strains were correct. This point has been added to the manuscript, as well as "…at the relevant experimental temperature" in the sentence describing compliance, to clarify that the different behaviour of the machine at temperature is also accounted for. To clarify, the method to quantify strain in deforming porous samples in Quane et al., (2004) *and Quane and Russell* (2005) *may be applied for glass-bead compacts, but unfortunately not for natural multi-phase material.*

Without post-experiment characterization (on samples that will allow it-sometimes even brittle deformation samples can be salvaged and epoxyed), the authors cannot speak with authority on the types of deformation occurring. Unfortunately, by not having that authority, the Conclusions they draw come into question. Certainly, the authors can do an analysis of the run products and produce a figure or two (like Figure 3 does for pre-experiment cores) to describe the major mechanisms of deformation and strain accommodation. Without this, this otherwise very strong, methodical and detailed contribution falls incomplete.

As mentioned above, this study is first and foremost concerned with a description of the macroscopic deformation modes of lava, not the deformation mechanism. Yet, we fully agree that textural information provides insight into the underlying microscopic deformation mechanism. We draw the reviewer's attention to the newly created Figure 5 and Figure 12 a). Due to the fragmental nature of the samples, particularly those marked as having a brittle or brittle-dominated response, it was impracticable to reconstruct the position of each fragment with epoxy, yet we looked at some fragments (new Figure 5) taken from the inner part of the sample. We provide new data in Figure 10 (now Figure 12), containing photographs of the run-products and accompanying comments in the manuscript. With the photographs, the now more detailed explanation of the curves, and the SEM images in Figure 5, we believe we have satisfied the reviewers concerns about sample characterisation.

Technical corrections in this manuscript a very minimum. Found one spelling mistake, but I lost it!

We thank the reviewer for searching the document for typos, we have found the assaulting spelling mistake mentioned and have track changed it in the manuscript.