Response to referee #1 for GChron-2020-30

The review of referee #1 is in black, and our response is in blue.

Referee #1: Jocelyn McPhie

I was surprised to be asked to review this manuscript as I had reviewed a previous version for another journal earlier this year. I made that prior review clear when I accepted the review request. My prior review has not been acknowledged by the authors, even though they incorporated many of the changes I suggested and made corrections to errors I had identified.

A previous version of this manuscript was indeed reviewed by Dr. McPhie and we also followed her advice to submit the paper to a journal with an emphasis on geochronological work. The detailed suggestions and constructive criticism of Dr. McPhie considerably improved the version of the submitted manuscript. However, we were not sure how to handle this in the acknowledgements, since this is a new submission to another journal. However, we very much appreciate that Dr. McPhie has given twice constructive criticism and detailed comments on two versions of this geochronological work, and we will, of course, acknowledge both her reviews in the final manuscript.

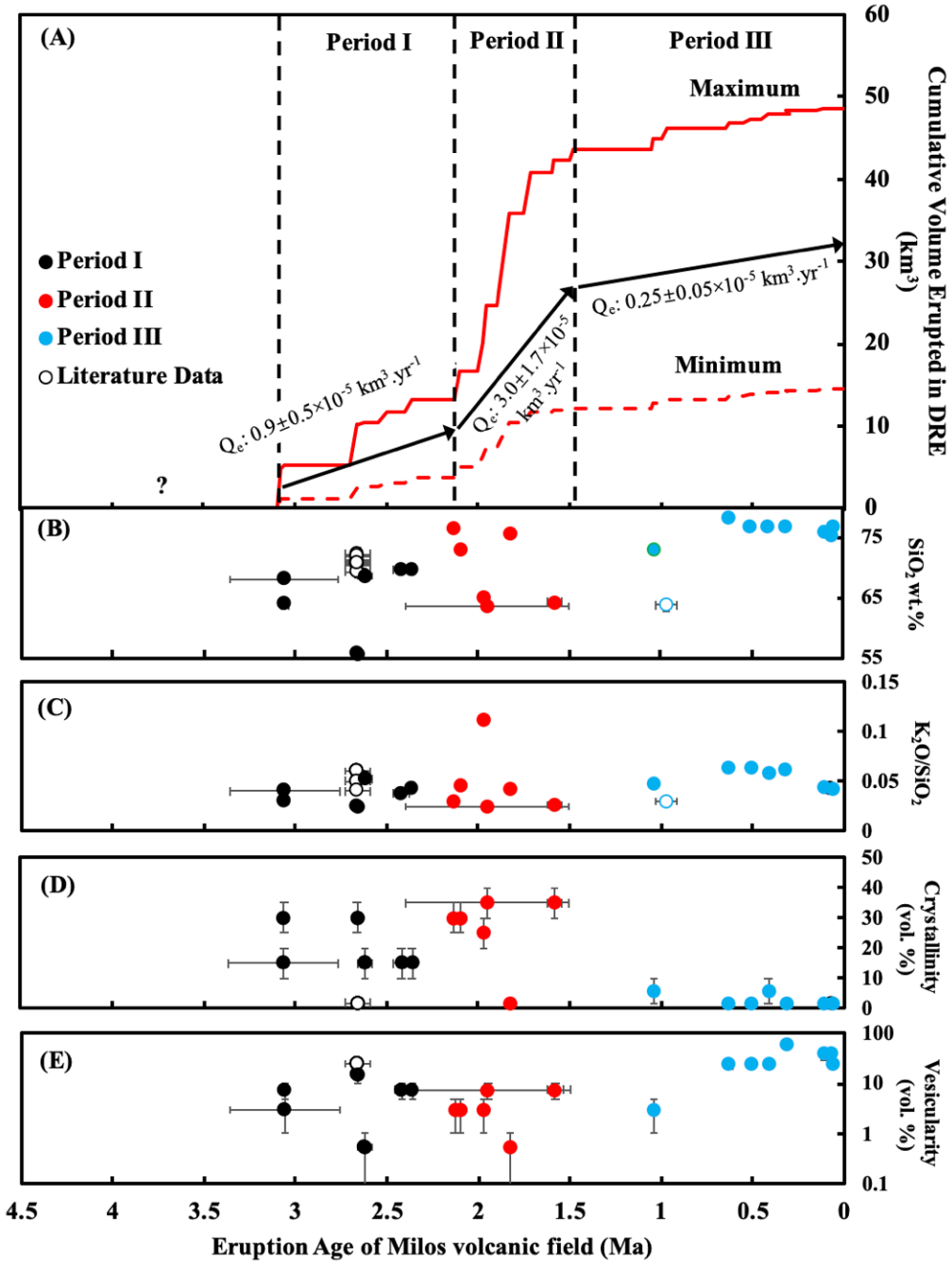
That said, this manuscript has the potential to contribute important geochronological data on the volcanic history of Milos. Geochronological data are a critical element in understanding volcanic evolution and are often lacking in volcanological studies. I am not a geochronologist and cannot critically assess the quality of the geochronological methods and data presentation. The authors have thoroughly researched previous geochronology studies on Milos and competently present the context.

We thank Dr. McPhie for the nice words for the geochronological data and literature review.

One of the fundamental flaws I identified in the previous version persists in this version. The authors propose numerous "phases" of volcanic activity lasting tens to hundreds of thousands of years separated by equally numerous and variably long periods of "volcanic quiescence" based on their new dates and existing dates on volcanic units. However, the notion of successive "phases" is misleading because of the implication that the phases are periods of continuous volcanism. The dated eruption events in fact occupy geological "instants", the longest activity being that of large domes and dome complexes that might take months to years to decades to be emplaced (still geologically instantaneous). Allied to this is the misconception that there were distinct quiescent periods. Most of the history of Milos was volcanic quiesence. Essentially each of the proposed phases is based on the age of one or a couple of volcanic centres (that is why there are so many) without any regard to patterns in the location, style and composition of volcanism. The division of the evolution into active phases and quiescence does not add to our understanding of the evolution of Milos or indeed any volcanic edifice. The result of this approach is confusion rather than clarity.
Correction of this flaw requires thorough revision of section 4.3 in the Discussion and all of the Conclusions (and part of the Abstract). Also, because this manuscript does not present any new volcanological data, much of the volcanological interpretation in this section (4.3) which has been taken from the cited references ought to be deleted. The revised section 4.3 could

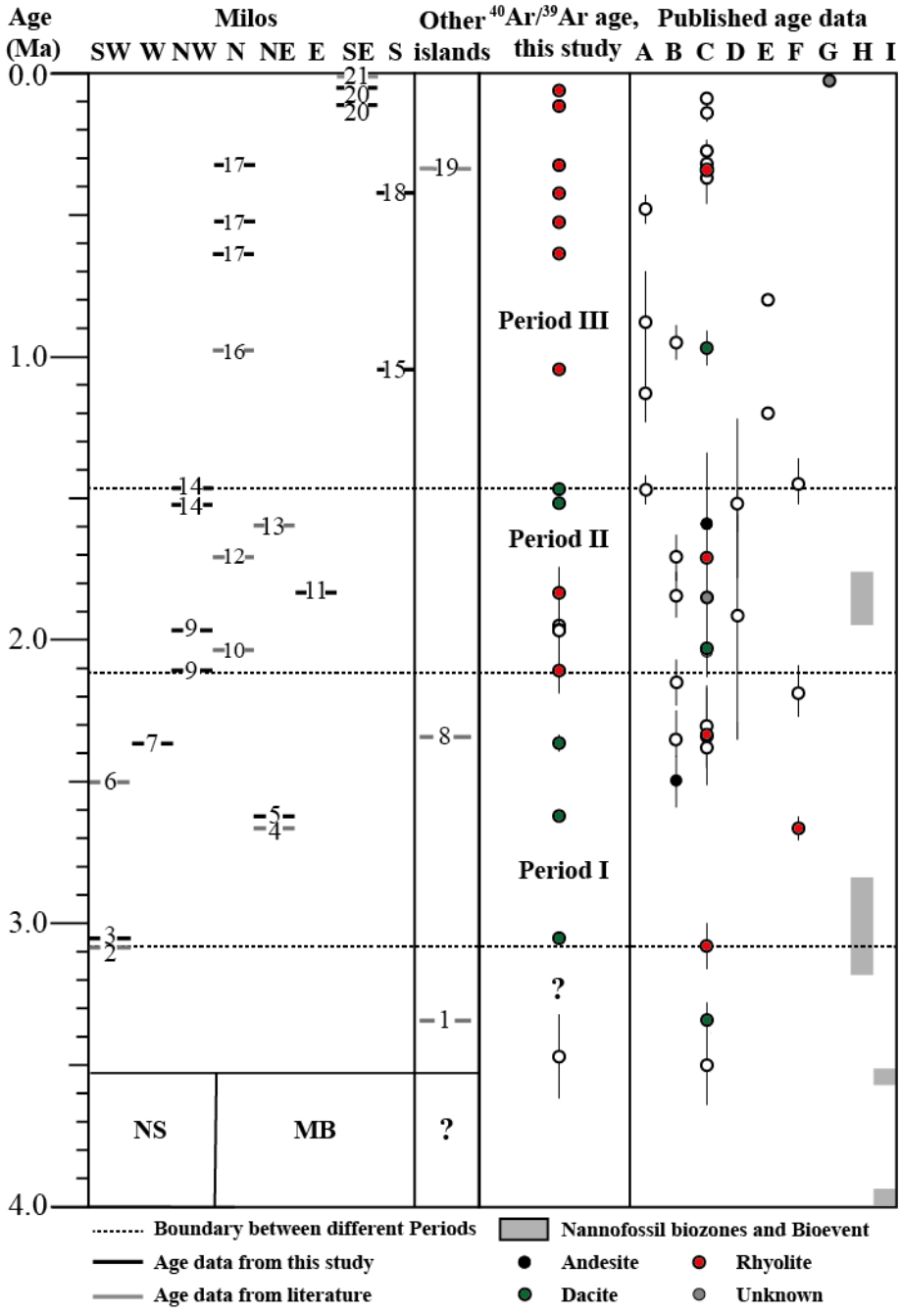
describe the tempo of edifice growth and the spatial distribution of volcanic centres through time without resorting to artificially defined phases.

We accept Dr. McPhie's argument that the Milos Volcanic Field (VF) was in states of quiescence for most of the time and only interrupted by brief episodes of volcanism in the ca 3.5 Ma volcanic evolution of the Milos VF. Although we did clarify in this version of the manuscript how we define our concept of phase (location, volcano type, composition), this was not made sufficiently clear to the reviewers (see also the review of Dr. Wotzlaw). We, therefore, decided to follow the suggestions of both reviewers to focus on the volumetric growth of the Milos VF (our Fig. 12), and define two periods of slow growth, and one with fast growth. This volumetric growth curve is based on our new $^{40}Ar/^{39}Ar$ data in combination with previously published surface area and thickness data from Fytikas et al., 1986 and Stewart and McPhie, 2006. These "periods" of slow/fast growth of the volcanic edifice are clearly defined and will be used in a second paper to predict the eruption frequency and the magma flux from depth. Figure 11, 12 and 15 will be updated and combined to new figures 11 and 14, and are shown below. These two new figures are crucial for the discussion and have been updated to incorporate the suggestions from Dr. McPhie and Dr Wotzlaw. We will rewrite section 4.3 as suggested based on these new figures and Table 5.


(A)
Period I
Period II
Period III
Maximum
Minimum
Period I
Period II
Period III
Literature Data
Qe: 0.9±0.5×10-5 km3.yr-1
Qe: 3.0±1.7×10-5 km3.yr-1
Qe: 0.25±0.05×10-5 km3.yr-1
?
Cumulative Volume Erupted in DRE (km3)
(B)
SiO2 wt.%
(C)
K2O/SiO2
(D)
Crystallinity (vol. %)
(E)
Vesicularity (vol. %)
Eruption Age of Milos volcanic field (Ma)

New Figure 11 (we combined Figure 11 with 12 of the original version).

Eruption age versus (A) cumulative eruption volume for the volcanic deposits of Milos, (B) SiO2 wt.%, (C) K2O%/SiO2%, (D) crystallinity vol. % and (E) vesicularity vol. % of Milos volcanic units of this study and previous studies. The maximum (Max; red line) and minimum (Min; dashed red line) cumulative eruption volume curves were estimated from Campos et al. (1996) and Stewart and McPhie (2006). Qe is the long term volumetric volcanic output rate. The exact volume of volcanic products between 4.1 and 3.08 Ma is poorly constraint and indicated with a question mark. In this study, estimates of crystallinity and vesicularity of the older samples (>1.0 Ma) are all from lava and domes whereas those of the younger samples (<1.0 Ma) are from pumiceous pyroclastic units. The major element, crystallinity and vesicularity data of the pumice deposits of the Filakopi volcano (2.66 Ma) are from Stewart (2003) (black open circles). The major element data of the Plakes lava dome is from Fytikas et al. (1986) (blue open circle). Geochemical, crystallinity and vesicularity data of the old pumice deposits of the Profitis Illias (~3.08 Ma) is lacking due to the severe alteration.


Age (Ma)
Milos
SW W NW N NE E SE S
Other islands
$^{40}Ar/^{39}Ar$ age, this study
Published age data
A B C D E F G H I
0.0
1.0
2.0
3.0
4.0
Period III
Period II
Period I
?
NS
MB
?
Boundary between different Periods
Age data from this study
Age data from literature
Nannofossil biozones and Bioevent
Andesite
Dacite
Rhyolite
Unknown

New Figure 14 (Figure 15 in the original version).

Diagram illustrating the three periods of different long term volumetric volcanic output rate of the Milos volcanic field based on the new $^{40}Ar/^{39}Ar$ data of this study and published age data. The location of the different volcanoes is given in Fig 3. and indicated in the left panel (from left to right: SW, W, NW, N, NE, E, SE and S of Milos. Other islnds include Kimolos, Polyegos and Antimilos). The two right panel corresponds to the new $^{40}Ar/^{39}Ar$ ages of this study and published age data: [A]=Fytikas et al., 1976, [B]=Angelier et al., 1977, [C]=Fytikas et al., 1986, [D]= Bigazzi & Radi, 1981, [E]=Matsuda, 1999, [F]=Stewart and McPhie (2006), [G]= Trainau and Dalabakis, 1989, and Biostratigraphic data of the Neogene sediments (NG) is from [H]=Calvo et al. (2012) and [I]=Van Hinsbergen et al. (2004) calibrated to Gradstein et al. (2012) (LCO of Sphenolithus spp. and FO of D. tamalis). In the two left panels, the number represents the volcanic centres on Milos (see details in Table 5), and black and grey lines indicate new $^{40}Ar/^{39}Ar$ data of this study and the preferred published age data for volcanic centres/units without available $^{40}Ar/^{39}Ar$ data, respectively. The start of volcanism (3.34-3.54 Ma) on Milos is poorly constraint and indicated with question marks (see text for discussion). The simplified basement cross-section (NS: Neogene sediments and MB: Metamorphic basement) below the Milos volcanic units is based on Fytikas et al. (1989).

We propose now to divide the volcanic history of Milos into three periods (3.08-2.13 Ma, 2.13-1.48 Ma and 1.48-0.06 Ma) of different long term volumetric volcanic output rate (Q_e). Figure 11 of this manuscript shows that these three periods have a different tempo of edifice growth (variable Q_e). The SiO_2 content, crystallinity and vesicularity of the volcanic outputs of the Milos VF vary through time.

Table 5. Summary of the eruption ages of the Milos volcanic field (The name of volcanic centre/unit or fossil content in the sediments corresponds to the number in the left panel of new Figure 14).

No.	Name of volcanic centre	Age (Ma)	Reference
1	Kimolos volcano	3.34	Fytikas et al., 1986
2	Profitis Illias crypto/pumice cone	3.08	Fytikas et al., 1986
3	coherent dacite of Profitis Illias volcano	3.06	This study
4	Filakopi volcano	2.66	Stewart and McPhie, 2006
5	Kalegeros cryptodome	2.62	This study
6	Mavro Vouni lava dome	2.5	Angelier et al., 1977
7	Mavros Kavos lava dome	2.42-2.36	This study
8	Polyegos lava dome	2.34	Fytikas et al., 1986
9	Triades lava dome	2.13-2.10 and 1.97	This study
10	Adamas lava dome	2.03	Fytikas et al., 1986
11	Dhemeneghaki volcano	1.83	This study
12	Bombardo volcano	1.71	Fytikas et al., 1986
13	Korakia dome	1.59	Fytikas et al., 1986
14	Komntaro dome	1.52-1.48	This study
15	Halepa lava dome	1.04	This study
16	Plakes lava dome	0.97	Fytikas et al., 1986
17	Trachilias complex	0.63, 0.51 and 0.317	This study
18	Kalamos lava dome	0.41	This study
19	Antimilos domes	0.32	Fytikas et al., 1986
20	Fyriplaka complex	0.11 and 0.07-0.06	This study
21	Phreatic activity	200 AD-200 BC	Trainau and Dalabakis, 1989

Section 4.1 should be reduced to half its present length by omitting the irrelevant review of geochronological methods. Such review is appropriate for a thesis but not appropriate for a paper.

The details of the $^{40}Ar/^{39}Ar$ age technique required in the paper depend on the background of the reviewers, as we have already discovered with the previous version of this manuscript. Reviewers with a volcanological/petrology/geochemical background want these sections reduced or removed, whereas reviewers with a background in $^{40}Ar/^{39}Ar$ geochronology argue that the discussion of the $^{40}Ar/^{39}Ar$ data is too limited. Given that we have followed the suggestion of Dr. McPhie and submitted a revised manuscript to a journal in the field of geochronology, we propose a compromise that satisfies the concerns of referees from both communities by presenting the $^{40}Ar/^{39}Ar$ data in such a way that both communities are satisfied by reducing figures 5-9 and moving most of the detail in the individual step discussion of the $^{40}Ar/^{39}Ar$ results of figures 5-9 to the supplementary material.

This version of the manuscript incorporates some interesting data on magma production rates and comparisons with other arc settings. These topics can be legitimately be covered because they don't depend on original data having been presented, and instead depend on the available literature.

We do not understand the point made by Dr. McPhie here. We discussed the temporal variations in the long term volumetric volcanic output rate (Q_e) of the Milos VF in section 4.5. This section includes the estimations of the long term volumetric volcanic rate and magma production rate for the Milos VF. We did these estimates mainly based on our twenty-one new $^{40}Ar/^{39}Ar$ ages, and previous geochronological and volcanological works of Fytikas et al. (1987) and Stewart and McPhie (2006). The Q_e is the expression of magmatism on the surface of the earth.

In contrast, the magma production rate is the representation of magmatism in or underneath the crust. We tried to find the solution to connect Q_e to magma production rate by discussing the ratio of the volumes of intruded magma in the crust to the volcanic units extruded onto the surface (I:E). This ratio is obtained from the study of White et al. (2006) that suggests a ratio of 5:1 as a realistic estimate for most volcanic centres. Our calculation of the magma production rate is comparable to that underneath the Kameni island of the caldera of Santorini (e.g. Druitt et al., 2019). However, considering no data of the magma volume in the crust underneath Milos having been measured, we admitted that we could only give a very rough estimate on the magma production rate. Although this rough estimate relies on a formula that comes from the literature (Jicha and Jagoutz, 2015), it still needs our geochronological data to constrain the different periods of different rates of volcanic output and/or magma production. Therefore, we felt that it is necessary to keep these topics instead of omitting them.

There are numerous English errors. I corrected some but not all on the annotated text and the figures (attached - please download for these corrections and further comments). Some of the figures need further work - confusing labels or labels that are inconsistent with the caption or the text.

We will rectify the language mistakes in the main text and figures as suggested by Dr. McPhie.

Please also note the supplement to this comment:
https://gchron.copernicus.org/preprints/gchron-2020-30/gchron-2020-30-RC1supplement.pdf.

We appreciate the suggestions that Dr. McPhie has made and we will accommodate many of them in our revised manuscript, should the editor invite us to submit the revision.