AGES OF OCEANUS PROCELLARUM BASALTS AND OTHER NEARSIDE MARE BASALTS.  H. Hiesinger and J.W. Head III, Department of Geological Sciences, Brown University, Providence RI 02912, USA (Harald.Hiesinger@Brown.edu).

Abstract

In a previous paper [1] we reported on crater size-frequency distribution data for 139 spectrally and morphologically defined basalt units in 6 nearside impact basins (Australe, Tranquillitatis, Humboldtianum, Humor, Serenitatis, and Imbrium). We also presented results on the relationship between titanium concentration and age of a basalt unit, the influence of crustal thickness on the eruption of a basalt onto the lunar surface, and the flux of lunar mare volcanism. In this paper we expand our study to Oceanus Procellarum in order to include the largest mare basalt-covered area into our investigation.

Introduction

It is known that lunar mare basalts cover about 17% of the lunar surface but represent only 1% of the volume of the lunar crust [2]. A significant portion of lunar mare basalts are exposed within Oceanus Procellarum and for large areas absolute age data are still lacking. From geologic mapping we know that there are very young basalts around crater Lichtenberg, but how old are they really? How do Oceanus Procellarum basalts compare to basalts in the newly investigated basins? Whitford-Stark and Head [3] defined 21 basalt types in Oceanus Procellarum and these basalts show ages from 3.8 b.y. to 2.4 b.y. [4]. Our approach is to use previously published maps [e.g. 3,5] as a basis to define homogeneous basalt units on Clementine color ratio mosaics and to perform new crater counts for these basalts. This is similar to the approach we took for our previous study [6,7].

Results and Conclusions

On the basis of analysis of eastern and central nearside mare basins we addressed following questions:

1. How long was lunar mare volcanism active?: Our data show that lunar volcanism was active for at least 2.0 b.y. According to our data volcanism started at about 4.0 b.y. and ceased at 2.0 b.y. However, numerous dark halo craters in the Australe region suggest the presence of a cryptomare. We conclude that volcanism must have been already active, at least in the Nectarian Period. Schultz and Spudis [8] suggested that lunar mare volcanism may have started as early as 4.3 b.y. ago. The basalts that were dated in our previous study were erupted primarily in the Imbrian Period from 3.4-3.8 b.y. We found only a minor number of basalts which erupted during the Eratosthenian period. In addition, there was no evidence for basalts of Copernican age in the six investigated impact basins but such basalts are exposed in the Oceanus Procellarum [9]. In Oceanus Procellarum these basalts embay the Copernican crater Lichtenberg and it is thought that these basalts are the very youngest basalts on the lunar surface with an age as low as probably <1 b.y. [9]. In order to answer the question over what time span lunar volcanism was active, the absolute ages of the the Lichtenberg basals have to be known. Therefore we will measure the crater size-frequency distribution of these basalts as well as other basalts north of Lichtenberg which were mapped as Copernican basalts by Wilhelms [9]. Geologic mapping [9] also revealed that significant portions of Oceanus Procellarum are covered with Eratosthenian basalts. From these maps it seems that Eratosthenian volcanism was more widespread in Oceanus Procellarum than in other lunar mare basalt regions besides Imbrium. We will determine absolute ages for Oceanus Procellarum basalts in order to investigate variations in the activity of mare volcanism with time.

2. What is the spatial distribution of ages?: Soderblom et al. [10] reported differences in age, chemistry, and magnetism between basalts of eastern and western basins. According to this work, eastern basalts are in general older, more magnetized and less radioactive than their western counterparts. Results from Lunar Prospector [11] show high concentrations of thorium and potassium in and around the nearside western maria thus being consistent with Soderblom’s observations concerning the amount of radioactive elements. So far we investigated basalts in six lunar impact basins which are distributed over the entire lunar nearside, therefore allowing us to study large-scale differences in age and geochemistry between eastern and western basalts. Based on this investigation we found that volcanism was active longer in the western parts of the nearside than in the eastern regions. However, this trend is not very pronounced in our data and westernmost parts, i.e. Oceanus Procellarum are still missing. Geologic maps [9] show that large areas within Oceanus procellarum are covered with Eratosthenian basalts. These Eratosthenian basalts are exposed in the central parts of Oceanus Procellarum and Imbrium basalts are located closer to the highland/mare boundaries. We will test for this distribution and provide new age data for the Oceanus Procellarum basalts.

3. How does the titanium content vary with time?: For basalts in the six investigated basins we generally see that TiO$_2$-rich basalts tend to be older than TiO$_2$-poor basalts. Our results are consistent with the trend found in the sample collection that indicate that radiometric older basalts are generally richer in titanium than younger basalts. However, a very important result of our previous investigation is that the TiO$_2$-contents and ages of the basalts within each investigated basin are not correlated. Our data indicate that TiO$_2$-rich and TiO$_2$-poor basalts can erupt simultaneously in different locations within the basin. In each single basin the TiO$_2$-concentrations can vary independently from the ages of the units. This probably suggests a highly heterogeneous mantle or source region. With the recent study we wish to test if this observation also holds for Oceanus Procellarum basalts. Spectral mapping of ba-
salt types [5] indicate that for large parts of Oceanus Procellarum younger basalts are more titanium rich than older basalts, thus somewhat reversing the trend found in the returned samples. Because of the immense importance of this observation for the development of petrogenetic models absolute age determinations are necessary for these basalts.

4. How much basalt was erupted with time?: Once spectrally homogeneous units are mapped their areal extent can easily be measured. In combination with reasonable assumptions [e.g. 12] of the thickness of a basalt we are able to estimate the erupted basalt volume. In our previous study we assumed that a single basalt flow unit is ~10 m thick. For the basalts in the six investigated basins we see that the main volcanic activity occurred in the Imbrian Period and was at least larger by a factor of 3.5 between 3.4 and 3.7 by, compared to the period between 2.9 and 3.4 by. We conclude that mare volcanism was not equally active over long periods of time but peaked in the Imbrian Period. As mentioned above there are large areas in Oceanus Procellarum which were previously mapped as Eratosthenian in age [9]. We will investigate the influence of these basalts on the distribution of active mare volcanism over time. Is there a second peak of volcanic activity in the Eratosthenian Period or are the Eratosthenian basalts of Oceanus Procellarum part of the decline of volcanic activity observed in the other areas?

5. How does crustal thickness influence basalt eruptions?: Besides high-resolution color imaging data which are used for the definition of spectrally homogeneous units, Clementine provided us with estimates of the crustal thickness of most of the Moon [13]. In our previous study we used this data set and found that the maximum thickness of the crust where basalts occur is 50-60 km. Our results are consistent with results of Yingst & Head [14] and imply that crustal thickness is a limiting factor for the eruption of lunar basalts onto the surface. We see that ascending magmas preferentially extrude to the surface where the crust is thin, i.e. the lunar nearside or the impact basins. On the farside the crustal thickness is larger and therefore the magmas stall and cool in dikes before they reach the surface. Thickening of the crust with a related compressional stress field within the crust or sinking of the buoyancy trap over time makes it more and more difficult for dikes to extrude to the surface [15]. As a consequence, our data indicate that the youngest basalts are often exposed in or near areas with relatively thinnest crust. On the basis of this observations we conclude that in areas with a thinner crust dikes still could reach the surface even later in lunar history whereas in other regions the dikes stalled in the crust and could not propagate to the surface. In Oceanus Procellarum we will investigate the correlation between crustal thickness and corresponding age in order to test for if the youngest basalts are exposed over regions with systematically thinner crust and if our previous results also hold for the basalts in this area.

References