THE HANSTEEN AND HELMET VOLCANIC DOME REGIONS ON THE MOON: STRATIGRAPHY AND AGES. R. Wagner[1], J. W. Head III[2], U. Wolf[1], and G. Neukum[3], [1]Institute of Planetary Research, German Aerospace Center (DLR), Rutherfordstrasse 2, D-12489 Berlin, Germany; [2]Dept. of Geol. Sciences, Brown Univ., Providence, RI, USA; [3]Institute of Geosciences, Dep. of Earth Sciences, Freie Universität Berlin, D-12249 Berlin, Germany.

Introduction: Emplacement of basaltic low-viscosity mare materials was the dominant volcanic process on the Earth's moon. A spatially less abundant mode of volcanic activity is associated with domical features formed by lava materials of much higher viscosity. These **volcanic domes** are morphogically and spectrally distinct from their surrounding mare or highland materials. The domes are termed *red spots* and are spectrally characterized by (1) high albedo, (2) a strong absorption in the ultraviolet, and also (3) by a wide range of morphologies [1][2][3]. From photogeologic mapping and measuring crater frequencies on these domes and associated units, we expect to put constraints on the crustal evolution throughout the Imbrian and Eratosthenian periods of lunar geologic history.

Previous work: The Gruithuisen domes, located in northern Oceanus Procellarum at about 36° northern latitude and 40° western longitude, in relatively close proximity to the large crater Iridum, have been investigated recently [3][4][5]. Out of a total number of three domes in this area, on two of them the superimposed crater frequency could be measured on medium and high-resolution Lunar Orbiter frames. Following the large impact event which created the Imbrium basin 3.91 Gyr ago [6], Iridum crater was formed, and its ejecta were emplaced on top of Imbrium ejecta. Then, on a geologically short time scale after this impact event, the three Gruithuisen domes were created by extrusion of viscous lava, possibly similar in composition to terrestrial rhyolites or andesites [4][5]. From morphologic characteristics of these domes, yield strengths of $\sim 10^5$ Pa, plastic viscosities of $\sim 10^9$ Pa s, and effusion rates of ~50 m^3/s were estimated [5]. The domes remained active in the Late Imbrian epoch, between 3.85 and 3.7 Gyr ago [4], confirming an Imbrian age as has been suggested earlier [7]. This kind of high-viscosity volcanism was followed by the emplacement of large volumes of basaltic mare lavas, with model ages peaking at 3.55 Gyr, 3.2 – 3.3 Gyr and about 2.4 Gyr [4][8][9].

The Hansteen and Helmet regions in southern Oceanus Procellarum: Two areas featuring similar spectral red spots and volcanic domes were selected for on-going studies. Both areas are located in southern Oceanus Procellarum, close to the Humorum basin.

Hansteen region. Hansteen is a bright, polygonally shaped, domical feature located at about 11.5° southern latitude and 50° western longitude. The nearest major impact features are craters Hansteen , a crater whose floor is partly flooded by mare laves, and Billy with a floor completely flooded by lava materials.

Helmet region. This region includes at least one minor domical feature at about 16° southern latitude and 30° western longitude located at the northwestern edge of the Humorum basin and is mostly covered by mare materials. The name is derived from the "helmet"-shaped area with a dome and plains which are brighter than surrounding mare materials.

Data base and procedure: Photogeologic mapping and measurements of crater frequencies in the Hansteen-Helmet region were carried out on Lunar Orbiter high-resolution frames LO IV 149, 156 (both Hansteen), and LO IV 132 and LO IV 137 (Helmet). Geologic units were distinguished by albedo and morphology, previously published maps were used as references (e.g. [10][11]). Crater size-frequency distributions were fitted by an 11th-degree polynomial representing the time-invariant lunar crater production function in order to extract relative ages (normally the cumulative frequency equal to, or greater than, a diameter of 1 km). Then, the lunar cratering chronology model calibrated by the radiometric ages of lunar rocks returned during the Apollo missions [6] was applied to derive absolute ages for each unit.

Hansteen region – ages and stratigraphy: Crater frequencies broadly confirm the stratigraphic relationships between geologic units (*figure 1*). In the case of some units, however, their stratigraphic positions had to be corrected by means of crater counts. On two areas on Hansteen dome, model ages range from 3.74 to 3.6 Gyr, ages which are comparable to those measured on the Gruithuisen domes. The Hansteen dome was assumed to be Eratosthenian or even Copernican by [11] but could now be verified as Late Imbrian by crater counts. Surrounding mare materials also could be verified as Late Imbrian, instead of Eratosthenian [11], while Early Imbrian ages were confirmed for craters

Hansteen or Billy, with model ages of about 3.8-3.9 Gyr. On these latter craters, smaller superimposed craters were removed along slopes of the rims and ejecta materials of these two larger craters causing a flatter slope in the crater size distribution towards smaller craters. Spectral analyses carried out recently also confirm that the Hansteen dome was emplaced on top of the ejecta materials of craters Hansteen or Billy [12]. *Figure 1* is a cumulative diagram showing the stratigraphic relations between the oldest units (such as crater Billy), the Hansteen dome, and the younger mare materials.

Helmet region – ages and stratigraphy: Crater frequencies of some key units are shown in *figure 2*. As in the Gruithuisen and Hansteen regions, a Late Imbrian age could be verified for the dome and surrounding volcanic plains (3.8 Gyr) while mare materials range from 3.88 Gyr to 3.17 Gyr (Late Imbrian to Early Eratosthenian). Crater Darney C could be dated as Late Imbrian/Early Eratosthenian (3.18 Gyr).

Summary: Results from these two areas, and from the Gruithuisen region, show that high-viscosity dome volcanism was active at the beginning of the Late Imbrian epoch at about 3.8 to 3.7 Gyr in all three regions and has remained active for at least 100 Myr. Basaltic mare volcanism in these areas, however, has lasted for several 100 Myr into early Eratosthenian (e.g. from 3.6 – 3.15 Gyr). Hence, volcanic activity producing lava materials of higher viscosity was not only restricted to a small number of localities but also was short-lived compared to mare volcanism

References: [1] Wood C. A. and Head J. W. III (1975), Papers presented at the *Conference on Origin of Mare Basalts*, Lunar Sci. Inst., Houston, Tx., 1151–1154. [2] Head J. W. III et al. (1978) *LPSC IX.,* 488-489. [3] Chevrel S. D. et al. (1999), *J. Geophys. Res. 104, No. E7,* 16,515-16,529. [4] Wagner R. et al. (2002), *J. Geophys. Res. 107*, 14-1 – 14-15,. [5] Wilson L. and Head J. W. III (2003), *J. Geophys. Res. 108*, 6-1 – 6-7. [6] Neukum G. et al. (2001), in: *Chronology and evolution of Mars* (W. K. Hartmann, J. Geiss, and R. Kallenbach, eds.), p. 53 – 86, Kluwer Acad. Publ., Dordrecht, NL. [7] Head J. W. and T. B. McCord (1978), Science 199, 1433-1436. [8] Hiesinger H. et al. (2000), *J. Geophys. Res. 105*, 29,239-29,275. [9] Hiesinger H. et al. (2003), *J. Geophys. Res. 108*, No. E7, 5065. [10] Scott D. H. et al. (1977), Map I-1034, *Misc. Inv. Series*, U. S. Geol. Surv. [11] McCauley J. F. (1973), Map I-740 (LAC-74), *Geol. Atlas of the Moon*, U. S. Geol. Surv. [12] Hawke B. R. et al. (2003), *J. Geophys. Res. 108*, No. E7, 5069. [13] Titley S. R. (1967), Map I-495 (LAC-93), *Geol. of the Moon*, U. S. Geol. Surv.

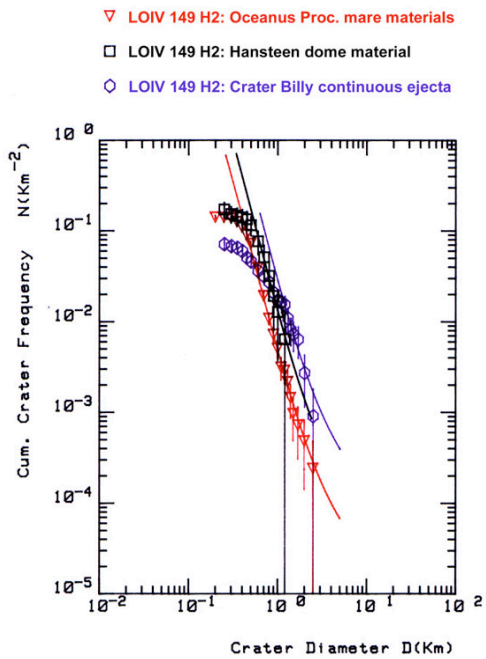

Figure 1: Cumulative frequencies of dome, mare and crater materials in the *Hansteen region*.

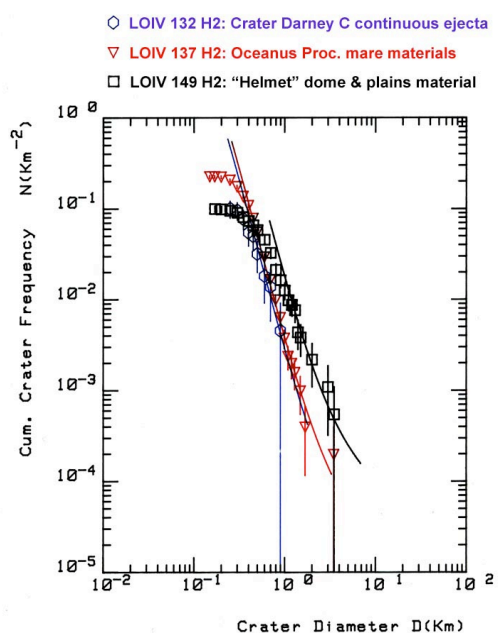

Figure 2: Cumulative frequencies of dome and plains, mare and crater materials in the *Helmet region.*