

STRATIGRAPHIC SEQUENCE AND AGES IN THE GRUITHUISEN REGION OF THE MOON. R. J. Wagner¹, J. W. Head III², U. Wolf¹, and G. Neukum¹. ¹DLR, Institute of Space Sensor Technology and Planetary Exploration, Rutherfordstrasse 2, D-12489 Berlin, Germany, e-mail: Roland.Wagner@dlr.de, ²Dept. of Geological Sciences, Brown University, Providence, Rhode Island, USA.

Introduction: The *Gruithuisen* region in northern Oceanus Procellarum on the moon (fig. 1) features several domes, morphologically and spectrally distinct from surrounding mare and highland units, and therefore is indicative of non-mare volcanism. In order to assess the stratigraphic relationships in this region, we carried out geologic mapping and crater size-frequency measurements (1) on the Gruithuisen volcanic domes, (2) on the adjacent mare and (3) highland units, and (4) on the ejecta blanket of the nearby Iridum crater. A recently updated and improved version of the lunar crater production function polynomial was used to fit measured crater size-frequency distributions of geologic units, and a cratering chronology model was applied in order to assign these units to the periods and epochs of lunar stratigraphy and chronology. Mapping and crater size-frequency measurements were carried out on both medium- and high-resolution Lunar Orbiter V frames for the Gruithuisen region, and on high-resolution Lunar Orbiter IV frames for Iridum crater, which are about a factor of eight lower in resolution compared to the image data from the Gruithuisen region.

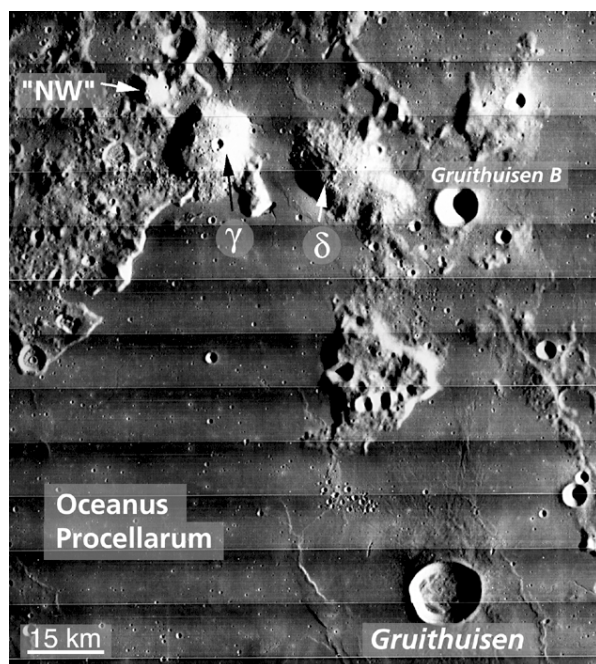


Figure 1: *Gruithuisen* volcanic domes (γ , δ , and northwestern (NW)) and mare areas in Oceanus procellarum.

Geologic setting: The *Gruithuisen Region* investigated in this paper is located in northern Oceanus Procellarum between lat. 40° and 20° N, long. 38° and 45° W and covers an area of about 130x100 km (fig. 1). It exhibits *three volcanic domes* (γ , δ , and NW), associated with highland and mare materials. A steep scarp separates the gently sloped or rugged highland materials from the relatively smooth mare materials of the Oceanus Procellarum. Kilometer-sized secondary craters from the Imbrium and Iridum ejecta events are abundant in the highland area. Non-mare volcanism is indicated by spectral features known as *red spots* which are characterized by (a) a high albedo, (b) a strong absorption in the ultraviolet, and (c) a wide range of morphologies, including volcanic constructs such as the *Gruithuisen* domes [1, 2].

Crater size-frequency measurements and cratering model ages: Results from crater size-frequency measurements are presented in cumulative diagrams, showing crater frequencies equal to, or greater than, a given diameter (1 km in general), versus crater diameter on a log-log plot [3]. Crater distributions, measured on geological units of various ages and in overlapping diameter ranges, can be aligned along a complex curve by a vertical shift, i.e. in $\log-N_{cum}$ -direction [4]. This curve, described by a polynomial of 11th degree, represents the time-invariant *lunar production function* which is used to fit measured data, and to derive a relative crater retention age (in general at a reference diameter of 1 km) [4, 5, 6]. This polynomial was refined and improved recently [6, 7]. A cratering chronology model was derived from radiometric age data of lunar rock samples returned during the Apollo mission and used to obtain absolute cratering model ages for geologic units [4, 5, 6, 7].

Geologic units and ages: Cratering model ages of *Iridum ejecta materials* range from about 3.84 to 3.7 Gyr (1 Gyr = 1 billion years). Iridum ejecta were mapped outside the Gruithuisen region and hence are not shown in figs. 2 and 3. Two units were mapped in the *highlands* around the Gruithuisen domes (Ih_1 , Ih_2 ; figs. 3, 4) with Late Imbrian model ages of 3.8 Gyr and 3.55 Gyr respectively. The 3.8 Gyr age could stem from the Iridum impact event whereas the 3.55 Gyr model age is from a local, so far unknown resurfacing event. Two units were mapped on the Gruithuisen domes (figs. 2, 3, 4): dome material (Igd), and lava flow, or, equally possible, landslide material (Igf) with model ages ranging from 3.85 – 3.7 Gyr, inferring that

the Gruithuisen domes were volcanically active at the beginning of the Late Imbrian epoch. *Mare materials* (figs. 2, 3, 4) in the Gruithuisen area display the widest range of ages. Subsequent flows in Late Imbrian and Mid-Eratosthenian, or single flow events in Mid-Eratosthenian, created mare units with model ages of 3.55 Gyr, and 2 – 2.4 Gyr (units **Elm**, **Em**). Smaller areas of mare units north and south of the domes, and in topographically low regions within the highlands, feature Late Imbrian model ages of 3.2 – 3.3 Gyr. In both highlands and mare areas, units which could not be dated were mapped (unit **hmu**, highland and mare materials, undivided). This is either caused by poor crater statistics or by equilibrium distributions.

Summary: The following sequence of geologic events is confirmed by geologic mapping and crater statistics:

1. Subsequent to the formation of the large multi-ring structures Imbrium and Orientale, the 260-km crater Iridum was created about 3.84 to 3.7 Gyr ago. Highland areas around the Gruithuisen domes also show comparable model ages, hence could have been resurfaced by ejecta materials from Iridum.
2. On a geologically short time scale after the Iridum event (i. e. not resolvable by means of crater counts), the three Gruithuisen domes were created by extrusion of silica-rich, viscous lavas. Cratering model ages of the domes range from 3.85 – 3.7 Gyr, similar to Iridum.
3. Extensive, more fluid eruptions representing mare volcanism started about 150 Myr after the formation of the Gruithuisen domes and were active over a period of about 1 Gyr into Mid-Eratosthenian, with cratering model ages peaking at 3.55 Gyr, 3.2 – 3.3 Gyr, and about 2.4 Gyr. Mare volcanism in the Gruithuisen region was connected to emplacement of mare materials in Mare Imbrium (towards the east of the Gruithuisen region), featuring similar peak model ages of 3.5 Gyr, 3.3 Gyr and 2.5 Gyr [8].

References: [1] Wood C. A. and J. W. Head, *Conf. on Origin of Mare Basalts*, Lunar Sci. Inst., Houston, Tx., 1975. [2] Chevrel S. D. et al., *J. Geophys. Res.* **104**, No. E7, 16,515 – 16,529, 1999. [3] Arvidson R. et al., *Icarus*, **37**, 467 – 474, 1979. [4] Neukum G., *Habilitationschrift*, LMU München, Germany, 186 pp., 1983. [5] Neukum G. and B. A. Ivanov, in: *Hazards due to comets and asteroids* (T. Gehrels, ed.), 359 – 416, Univ. of Arizona Press, Tucson, 1994. [6] Neukum G. et al., in: *Chronology and evolution of Mars* (W. K. Hartmann, J. Geiss, and R. Kallenbach, eds.), pp. 53 – 86, Kluwer Acad. Publ., 2001. [7] Neukum G. and B. A. Ivanov, *Lunar Planet. Sci. Conf. XXXIII*, abstract #1263 [CD-Rom], 2002. [8] Hiesinger H. et al., *J. Geophys. Res.* **105**, No. E12, 29,239 – 29,275, 2000.

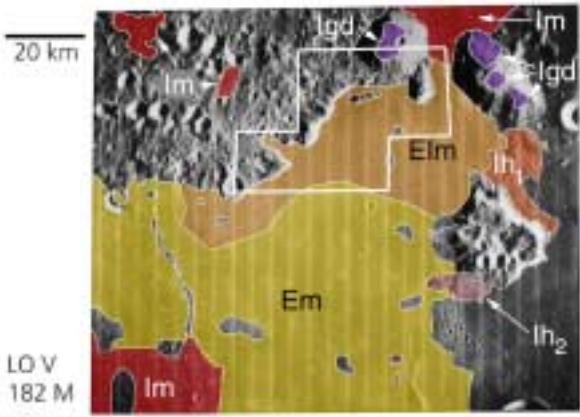


Figure 2: Geologic units mapped on Lunar Orbiter frame LO V 182 M (medium resolution).

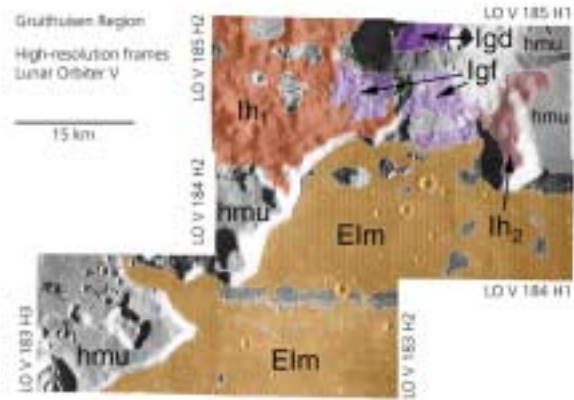


Figure 3: Geologic units mapped on Lunar Orbiter V high-resolution frames (183 H2, H3; 184 H1, H2; 185 H1, H2). Location of frames also outlined in fig. 2.

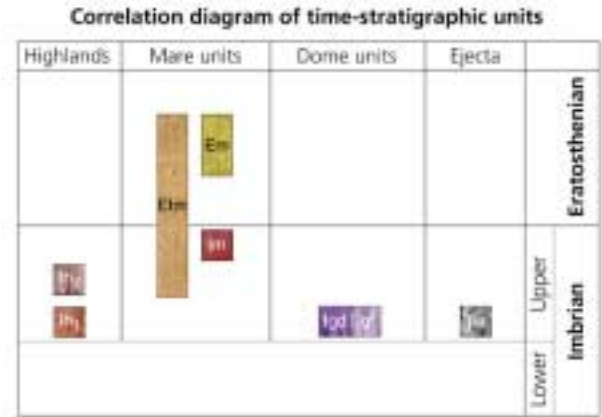


Figure 4: Correlation diagram of time-stratigraphic units mapped and dated in the Gruithuisen region.