Geological and geochemical analysis of units in the South Pole – Aitken Basin

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The South Pole – Aitken Basin

Largest and oldest Lunar impact basin
- Diameter > 2500 km
- Depth > 12 km
- Age 4.2 - 3.9 Ga → Formed during Late heavy bombardment?

Window into the interior and evolution of the Moon

Priority target for future sample return missions

Digital Elevation Model from Clementine altimetry data. Produced in ENVI, 50x vertical exaggeration, orthographic projection centered on the far side. Red +10 km, purple/black -10 km. (A.M.Borst et al. 2008)
The Moon and the SPA Basin

**Geochemistry**

South Pole – Aitken Basin mafic anomaly

- High Fe, Th, Ti and Mg abundances
- Excavation of mafic deep crustal / upper mantle material

Clementine 750 nm albedo map from USGS Map-a-Planet


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**What can we learn from the SPA Basin?**

- **Large impacts:** Implications and processes
- **Volcanism:** Origin, age and difference with near side mare basalts
- **Cratering record:** Age, frequency and size distribution
- **Late Heavy Bombardment:** Intensity, duration and origin
- **Composition of the deeper crust and possibly upper mantle**
1) **Global structure of the basin** (F.S. Bexkens et al, 2008)
   - Rims, rings, ejecta distribution, subsequent craters modifications, reconstructive geology
   - Data: Clementine LIDAR, SMART-1 AMIE

2) **Geochemistry and stratigraphic signatures**
   - 1) Identify mafic rock types and distribution, after Pieters and Tompkins (2001)
     \[\rightarrow\text{Norite, Gabbro, Basalt, Troctolite}\]
   - 2) Zoom in on gabbro/troctolite regions to identify and distinguish pyroxene or olivine abundances
     \[\rightarrow\text{Exposed upper mantle/deeper crust?}\]
   - Data: Clementine UV/VIS and NIR data (from Map-a-Planet)

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**Global geochemical analysis**

**Identification of mafic rock types with UV/VIS data**

Algorithm for Clementine UV/VIS data to distinguish between mafic rock types based on abundant olivine, pyroxene (high or low Ca) or plagioclase. Developed by Pieters and Tompkins (2001).

**Blue**
- Anorthosite = felsic, dominated by Ca-feldspar (anorthite), or weathered materials
  \[\rightarrow\text{Highland crust, weathered surface}\]

**Pink / Red**
- Norite = mafic, abundant low Ca-pyroxene
  \[\rightarrow\text{Lower crustal rocks}\]

**Green / Yellow**
- Gabbro and Troctolite = mafic, olivine and high Ca-pyroxene dominated
  \[\rightarrow\text{Mare basalts, lower crust/ upper mantle material}\]

Figure 6b. Spectra of the mafic minerals in Figure 6a resampled with the Clementine 750, 900, and 1000 nm filter bandpasses and scaled to unity at 750 nm.
Global geochemical analysis with UV/VIS


Real Color Composites

1) North West SPA
Leibnitz and Ingenii crater, basalts in Mare Ingenii, Leibnitz crater floor and Jules Verne basin (top left)

3) Central SPA
Complex craters with central peaks Alder, Bhabha and Bose, flooded crater Baldet and mare basalts in small craters above Bose

2) North East SPA
Large multiring-basin Apollo with 2 rims and dark mare basalts, dark Oppenheimer and Maksutov craters (left) and bright SPA rim (top right corner)

Clementine ‘Real’ color composites (1000 nm, 900 nm and 415 nm). Bands obtained from USGS Map-A-Planet website, processed in ENVI
Geochemical analysis with UV/VIS data

Anorthosite
Highland crust

Olivine Hill

Oppenheimer
Apollo mare basalts

Maksutov

Apollo

Apollo mare basalts

Basalt-Ol-Gabbro

(Pieters, 2001)

Gabbro

Jules Verne

Mare Imbrium

Thomson

Mare basalt

Flinten

Van Karmen

Local geochemical analysis (2)
Distinguishing olivine and pyroxene with Clementine

NIR data

Integration of NIR data allows better discrimination between olivine and pyroxene minerals in mafic rock types (gabbroic/troctolitic) dominated by these minerals than UV/VIS data only

2000/1250 nm ratio
(modified from LeMoeulic, 2002)

→ High values: Olivine dominated
→ Low values: Orthopyroxene dominated

Spectra of olivine (OLV) and orthopyroxene (OPX) mixtures (from Singer, 1981) convolved through Clementine filters.
Figure taken from Le Moeulic et al, 2002.
Local geochemical analysis with NIR data

Bhabha & Bose
Walls, central peaks and fresh craters: dark colors support abundant low Ca-pyroxene → expected

Olivine Hill
Fresh craters also have low values, no indication of olivine rich areas
→ unexpected
→ Mantle material more equally distributed?
**Summary**

**Two larger geochemical regions within SPA**
- **Norite** (low Ca-pyroxene dominated): Lower crustal material
  - Local: Leibnitz crater rim and central peaks of Finsen, Bhabha, Bose
  - Large scale: Apollo region (N-E SPA)
- **Gabbro** (high Ca-pyroxene dominated): SPA melt sheet, cryptomare
  - Large scale around N-W SPA

**NIR data:**
- Different characteristics volcanism on SPA interior and rim
- Complements observation of high Ca-pyroxene in noritic areas (Bhabha peaks)
- No clear detection of olivine (mantle material) in ‘Olivine Hill’

**Future work:**
- Multispectral analysis for mineral characterisation
  - Small scale, quantative spectral studies of Clementine NIR data
  - New multispectral datasets of future missions (Chandrayaan etc) will contribute for further analysis
- **SMART-1 AMIE mosaics for high res. geomorphological mapping**
Dhofar 961: meteorite from SPA Basin?

(B. Jolliff et al., 2008, LPSC)

Thorium (ppm)

ppm

Impact melt clasts (blue outline):

• Very mafic: FeO ~14 %, Th 1-5 ppm

Minerals:

Plagioclase, Pyroxene, mostly pigeonite (low-Ca, olivine)

Similar Th concentrations as in SPA (1 to 5 ppm)

Minor components of basalt (orange outline)

• Minerals:

Plagioclase, Pyroxene, mostly pigeonite (low-Ca, olivine)

Similar Th concentrations as in SPA (1 to 5 ppm)

Thank you!