



Groundwater at the southern pole of the Moon via the gravity strike angles: IM-1 and Artemis

Jaroslav Klokočník^{a,*}, Jan Kostecký^{b,c}, Aleš Bezděk^a

^a Astronomical Institute, Czech Academy of Sciences, Ondřejov, Frčíkova 298, CZ 251 65, Czech Republic

^b Research Institute of Geodesy, Topography and Cartography, Zdičky 98, CZ 250 66, Czech Republic

^c Faculty of Mining and Geology, VSB-TU Ostrava, CZ 708 33, Ostrava, Czech Republic

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ABSTRACT

Gravity strike angles are one of the gravity aspects. They are computed from global static gravity field models. They react to changes in density variation and porosity. Internal rock anisotropy and stresses can be detected by strike angles. They run parallel with the direction of weakness in the strength of the rock, e.g., the direction schistosity and/or the presence of faults or micro-fault zones. Thus, they can help to describe the underground causative body in another way than traditional gravity anomalies. We used the GRGM1200A gravity field model for the Moon to the degree and order of 600 in spherical harmonic expansion and LOLA topography. The results show that the strike angles are more frequently and more intensively aligned (combed) near the poles than in other places. The strike angles are highly combed for the Malapert A crater (the landing site of IM-1/Odyssey) as well as for the localities selected by NASA for the forthcoming Artemis missions. Our method, which has already been applied many times on diverse geological features on the Earth, provides quick and cheap remote sensing procedure, a preliminary diagnostic tool, independent of all others, in search of lunar water.

1. Introduction

This text is about a non-traditional search for lunar groundwater, using information derived from the gravity field model of the Moon. The paper contains not only the main text but also extensive *Supplements* (SMi). SM1 is about theory, SM2 is a tutorial about the gravity aspects, namely strike angles, and SM3 concerns the Moon's southern polar area, focused on the Artemis and IM-1/Odyssey landing places, with our new results. There is a link for download: https://www.asu.cas.cz/~jklokocn/MOON24_supplements/.

1.1. Intention – the main goal of this study

Subsurface (ground) water and ice on the Moon can now be considered as proven. Drinkable water is necessary for permanent human missions on the Moon. The local water sources could

help lunar colonists to survive. Further, at some future time, the water in rocks could be turned into **rocket fuel** (water needs to be split into oxygen and hydrogen).

This type of research is topical due to the recent progress in investigation of preparation of permanent human Moon's missions. The

successful landing of *IM-1/Odysseus* (Intuitive Machines, Nova-C lunar lander named Odysseus) at the Malapert A crater (near the southern pole) was an important step towards this aim (e.g., <https://www.intuitivemachines.com/im-1>; <https://nssdc.gsfc.nasa.gov/nmc/spacecraft/display.action?id=IM-1-NOVA>). There are the forthcoming Artemis programme missions (e.g.: <https://www.nasa.gov/feature/artemis/>; https://www.nasa.gov/wp-content/uploads/2020/12/artemis_plan-20200921.pdf). *Arnhof et al. (2022)* situated a future Moon Village base close to water ice resources near the southern pole and considered that the near constant illumination could provide enough solar power (more in Sect. 1.2.).

We contributed to the search for water on the Moon in an unexpected way (*Kletetschka et al., 2022*) and again contribute here by using the gravity aspects (*Klokočník et al., 2017a; 2020a*). We apply the global gravity field models of the Moon and the gravity aspects derived from them, namely combed gravity strike angles, which indicate changes in the porosity of surface material (regolith) or the higher porosity of subsurface layers (sediments). We predicted localities at the southern pole of the Moon where there is a higher chance of finding groundwater (*Kletetschka et al., 2022*) than elsewhere. We verify them here and extend them for the Malapert A crater (landing spot of the IM-1).

* Corresponding author.

E-mail addresses: jklokocn@asu.cas.cz (J. Klokočník), kost@fsv.cvut.cz (J. Kostecký), bezdek@asu.cas.cz (A. Bezděk).

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