# A two-billion-year-old KREEP-rich lunar meteorite, Northwest Africa 16895

*Mizuho Koike[1], Ryosuke Sakai[1], Ryoichi Nakada[2], Ben G. Rider-Stokes[3], Fumito Shiraishi[1], Kohei Sasaki[4], Naoto Takahata[4]

1. Hiroshima University , 2. Japan Agency for Marine-Earth Science and Technology, 3. The Open University, 4. The University of Tokyo

Northwest Africa (NWA) 16895 was found in Algeria in 2023 and was initially categorized as a martian augite basalt based on its petrology [1]. However, our mineralogical, geochemical, and in-situ U–Pb chronological analyses demonstrate that NWA 16895 may be a young lunar basalt [2–3]. Here we report that this meteorite represents a two-billion-year-old KREEP-rich lunar basalt, providing new insight into the late-stage lunar magmatism.

A polished section of NWA 16895 was prepared and briefly observed under a SEM-EDS. In-situ U–Pb and $^{207}$Pb–$^{206}$Pb dating was conducted on apatite, merrillite, Zr-bearing phases, and surrounding silicates using a NanoSIMS 50 at AORI, UTokyo [4]. Detailed mineralogy and elemental compositions were analyzed using a FE-SEM-FIB, TEM, and EPMA at N-BARD, Hiroshima Univ. Crystal orientations and internal microstructures of phosphates were examined using a SEM-EBSD at the Open Univ. [5–6]. Trace element compositions of the bulk-rock sample were measured using an ICP-MS at Kochi, JAMSTEC, after acid digestion and column chemistry [7]. Bulk-rock major element compositions were measured using an ICP-OES at Hiroshima Univ. High-precision oxygen three-isotope analysis of another bulk-rock was performed by laser-assisted fluorination at the Open Univ [5].

NWA 16895 is dominated by zoned pyroxenes (augite–pigeonite) intergrown with acicular plagioclase and ilmenite, accompanied by Fe-rich olivine, K-feldspar, silica, troilite, apatite, merrillite, and Zr-bearing phases (Fig. 1). Fayalite-silica symplectites occur along with apatite. Minor impact melt pockets are also observed. Pyroxene exhibit Mg-rich augite core and Fe-rich pigeonite rim, with Fe/Mn ratios of ~70–80 (Fig. 2). Their Ti# and Fe# show a broad agreement with lunar low-Ti basalts (Fig. 2). Plagioclase is Ca-rich and associated with K-feldspar. Apatite is rich in F, Fe, and Si. EBSD analyses reveal minor shock-related deformation in phosphates, while plagioclase is largely transformed into maskelynite.

A $^{207}$Pb–$^{206}$Pb isochron obtained from the analyses on phosphates, Zr-bearing phases, impact melt glass, silica, fayalite, and plagioclase yields an age of 2261 ±110 Ma (MSWD = 1.1; Fig. 3). The isochron slope indicates a highly radiogenic initial Pb component, corresponding to a source $\mu$-value of ~1500. Bulk-rock compositions are enriched in Fe, alkali elements (K, Na), Th and U, depleted in Al, and moderately low in Ti. REE abundances are ~100 ×CI chondrites, with a flat pattern and a negative Eu anomaly. The oxygen isotopic composition ($\Delta^{17}$O) is close to 0 ‰, confirming a lunar origin.

The textural and chemical characteristic identify NWA 16895 as a moderately low-Ti, low-Al, high-alkali, and KREEP-rich lunar basalt. The largely preserved crystal orientations of phosphates support an igneous crystallization age of 2261 ±110 Ma. This age closely matches that of a recently identified lunar meteorite, NWA 16286 (2201 ±13 Ma; [9]), and older than the Chang’e-5 basalts collected from lunar Oceanus Procellarum (2030 ±4 Ma; [8]), but distinctly younger than Chang’e-6 basalts from lunar far-side (2807 ±3 Ma; [10]). The geochemical and chronological similarities suggest that NWA 16895 and NWA 16286 may be paired, although the lithologies exhibit some differences.

 

References:
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Keywords: lunar meteorite, young KREEP-rich basalt, In-situ U–Pb dating, major and trace elements analyses, petrology and mineralogy

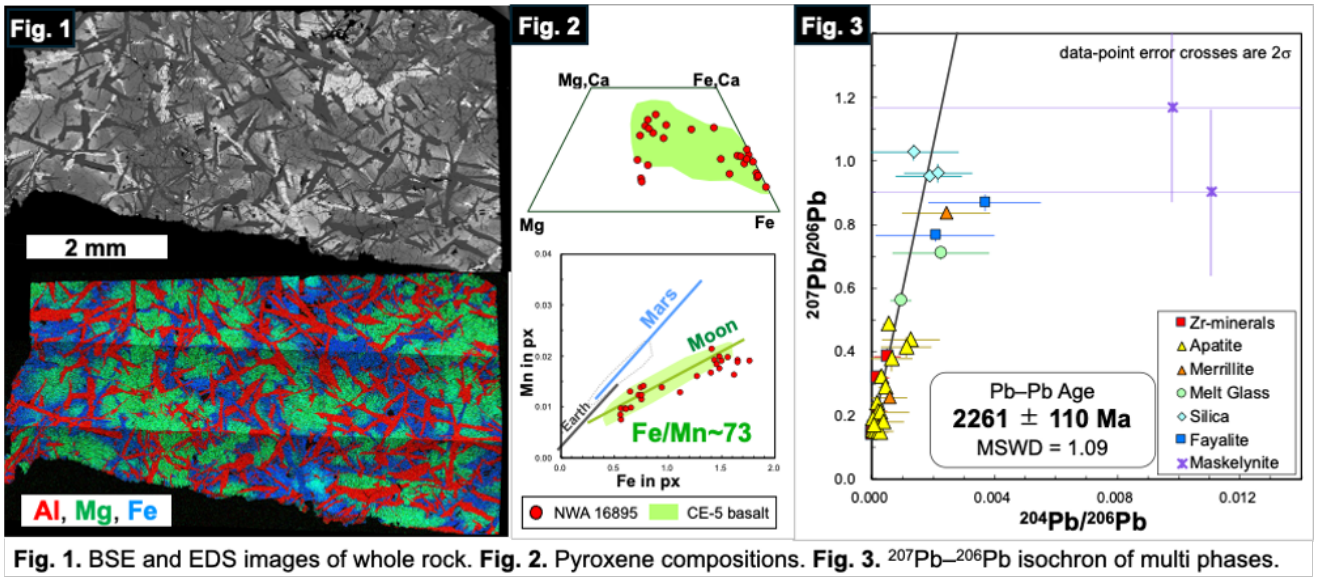


**Fig. 1.** BSE and EDS images of whole rock. **Fig. 2.** Pyroxene compositions. **Fig. 3.** $^{207}Pb$–$^{206}Pb$ isochron of multi phases.

 