U-Pb chronology of the unique achondrite Northwest Africa 6704. T. Iizuka[1], Y. Amelin[2], A. Yamaguchi, Y. Takagi[4], T. Noguchi[4] and M. Kimura[4] [1]Department of Earth and Planetary Science, University of Tokyo, [2]Research School of Earth Sciences, The Australian National University, [3]Antarctic Meteorite Research, National Institute of Polar Research, [4]College of Science, Ibaraki University.

Introduction:

Precise and accurate dating of meteorites is essential to understand the timescales for planetary formation and evolution. The U-Pb chronometer, based on two distinct radioactive decay schemes of ^{235}U–^{207}Pb and ^{238}U–^{206}Pb, can be potentially used to determine absolute ages of meteorites with high precision comparable to short-lived isotope relative chronometers (e.g., ^{26}Al-^{26}Mg and ^{182}Hf-^{182}W). Indeed, the U-Pb chronometer has been successfully applied to chronology of chondrites and basaltic achondrites [e.g., 1-3]. We have extended the application of the U-Pb chronometer to the non-basaltic achondrite Northwest Africa (NWA) 6704.

NWA 6704 is a new ungrouped fresh achondrite comprising abundant coarse-grained (up to 1.5 mm) low-Ca pyroxene, less abundant olivine, chromite, merrillite, and interstitial sodic plagioclase. Minor minerals are awaruite, heazlewoodite, and pentlandite. Raman spectroscopy indicates that orthopyroxene occupy the majority of low-Ca pyroxene. Oxygen isotopic study [4] showed that $^{18}O/^{16}O$ and $^{17}O/^{16}O$ of this meteorite plot within the field of acapulcoite-lodranite, although they do not share mineralogical and geochemical features.

Here we report preliminary Pb isotopic data for pyroxene fractions from the unique achondrite NWA 6704. The data suggest its significant antiquity and suitability as a time anchor for the short-lived isotopic relative chronometers.

Methods:

Pb isotopic analyses were performed on nine 10–20 mg aliquots of pyroxene. The aliquots of coarse pyroxene grains were grinded with an agate mortar before washing. Washing procedures were modified from Amelin [5]. All fractions were rinsed with distilled acetone and weighed before acid washing. The fractions were then washed 4-5 times in ca. 0.5 ml of 0.5 M HNO_3 with 10 minutes ultrasonic agitation during each leaching step. Ultrasonic washes were combined as the first washes. Subsequent, the fractions were washed twice with hot 6 M HCl, followed by twice washing with 7 M HNO_3, each step in about 0.5 ml of acid. Hot washes were combined as the second washes. All residues and leachates were spiked with mixed ^{202}Pb-^{205}Pb-^{229}Th-^{233}U-^{236}U tracer [6]. Spiked washes, with a few drops of concentrated HF added to dissolve any suspended fine silicate minerals, were evaporated to dryness, evaporated with 0.1 ml of 6 M HCl, 9 M HBr and re-dissolved in 0.3 M HBr. Spiked residues were digested in a HF+HNO_3 mixture, converted to a soluble form by repeated evaporation with 7 M HNO_3, 6 M HCl, 9 M HBr, and dissolved in 0.3 M HBr. Uranium and Pb were separated using columns with 0.05 ml of anion exchange resing AG1x8 200–400 mesh. Uranium and other major elements were eluted in 0.3 M HBr, and Pb was eluted with 0.5 M HNO_3. The Pb fractions were passed through the columns twice for complete separation of matrix.

Lead isotopes were analyzed on a TRITON Plus TIMS at the Australian National University as Pb^+. The analyses were essentially carried out with static multiple collector mode on Faraday cups, but for some of the second washes, peak jumping mode on the secondary electron multiplier was utilized. Furthermore, for the residues, because the signal of ^{204}Pb was small and the measured $^{206}Pb/^{204}Pb$ were relatively imprecise, the $^{205}Pb/^{204}Pb$ were additionally measured with the peak-jumping mode on the secondary electron multiplier, after completion of the Faraday cup run. Accuracy and reproducibility of Pb-isotopic measurements were monitored by analyses of NIST SRM-981 standard spiked with the same mixed tracer as the samples.

Results:

The first washes yielded Pb with $^{206}Pb/^{204}Pb$ between 20 and 27, whereas the second washes gave Pb with variable $^{206}Pb/^{204}Pb$ ranging from 20 to 80. The Pb isotopic compositions of the residues are much more radiogenic ($^{206}Pb/^{204}Pb$ between 130 and 2405). A Pb-Pb isochron for the seven most radiogenic residues (Fig. 1) yielded the age of 4563.7 ± 0.3 Ma, assuming of a $^{238}U/^{235}U$ value of 137.88. Furthermore, the isochron makes a close passage to the Pb isotopic composition of Nantan troilite [7], indicating that residual common Pb after the blank correction is primordial origin rather than terrestrial origin.

Discussion:

A $^{238}U/^{235}U$ value of 137.88 has long been considered invariant, but recent discovery of U isotopic variations in Ca-Al rich inclusions (CAIs) in chondrites shows that this assumption is invalid [8]. This indicates that not only Pb isotopic ratios but also $^{238}U/^{235}U$ need to be measured in order to determine accurate U-Pb dates [3]. Although U isotopic composition of NWA 6704 has not been determined yet, our preliminary Pb isotopic data for pyroxene fractions reveal that this meteorite is significantly old.

Radiogenic $^{207}Pb/^{206}Pb$ value (y-intercept of the Pb-Pb isochron) of NWA 6704 is substantially higher than those of the plutonic angrites and marginally lower than that of the quenched angrite D'Orbigny [5]. The data indicate that NWA 6704 is the oldest igneous rock in the solar system and only ~5 Myr younger than the CAIs, the solar system's earliest solids [3], unless $^{238}U/^{235}U$ of NWA 6704 is significantly lower than other bulk meteorites. Thus, this meteorite would provide valuable insights into the nature of magmatism on young planetesimals. In addition, given the significant antiquity, the freshness and the mineral assemblage including pyroxene, plagioclase, olivine, chromite and metal, NWA 6704 can provide an absolute age benchmark for various short-lived isotope relative chronometers (^{26}Al-^{26}Mg, ^{53}Mn-^{53}Cr and ^{182}Hf-^{182}W), i.e., both high precision absolute U-Pb age and initial abundances of the short-lived radionuclides can be determined. A new reliable time anchor is essential for evaluating the distribution of the short-lived radionuclides and for building a consistent time scale of the early solar system.

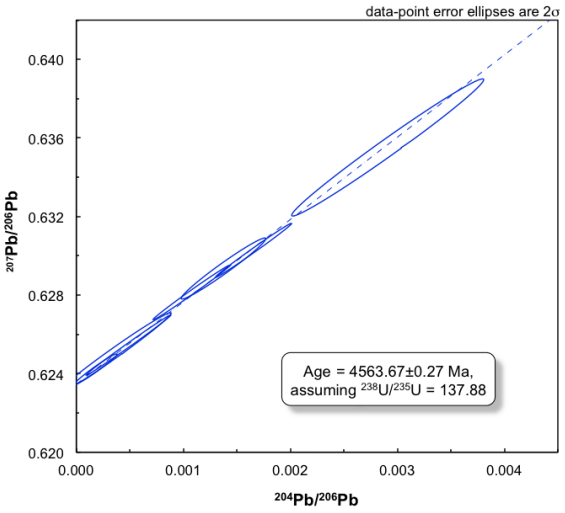

Fig. 1. Pb isotopic data for acid-washed pyroxene fractions from Northwest Africa 6704, plotted in a $^{207}Pb/^{206}Pb$ versus $^{204}Pb/^{206}Pb$ isochrons diagram.

References:

[1] Connelly J. N. and Bizzarro M. (2009) *Chem. Geol. 259*, 143–151. [2] Bouvier A. and Wadhwa M. (2010) *Nat. Geosci., 3*, 637–641. [3] Amelin Y. et al. (2010) *EPSL, 300*, 343–350. [4] Irving A. J. et al. (2011) *74th Metsoc abstract*, 5231. [5] Amelin Y. (2008) *GCA, 72*, 221–232. [6] Amelin Y. and Davis W. J. (2006) *JAAS, 21*, 1053–1061. [7] Blichert-Toft J. et al. (2010) *EPSL, 300*, 152–163. [8] Brennecka G. A. (2010) *Science, 327*, 449–451.