NORTHWEST AFRICA 6486. A MELT ROCK FROM THE L-CHONDRITE ASTEROID. C. A. Lorenz[1], E. V. Korochantseva[1,2], J. Hopp[2], I. Franchi[3], M. Humayun[4], S. N. Teplyakova[1], N. N. Kononkova[1], [1]Vernadsky Institute RAS, Kosygin St. 19, 119991, Moscow, Russia, c-lorenz@yandex.ru, [2]Institut für Geowissenschaften, Universität Heidelberg, Im Neuenheimer Feld 234-236, 69120 Heidelberg, Germany, [3]Planetary & Space Sciences, Open University, Milton Keynes, UK, [4]National High Magnetic Field Laboratory, Florida State University, USA.

Introduction: The L-chondrite melt rocks, comprising only 0.1% of L-chondrites [1], carry important information about the thermal history of the L-chondrite parent body. We report here the results of petrological, geochemical and geochronological investigations on the meteorite Northwest Africa 6486 (NWA 6486), an unusual K-rich L-chondrite melt rock.

Results: NWA 6486 is an achondritic rock of medium-grained porphyritic texture. The rock composes of subhedral and anhedral olivine (300-500 µm) and minor pyroxene grains settled in the groundmass of devitrified glass (Gl) and pyroxene (Px). Olivine (Ol) ($Fo_{77.3\pm0.4}$, N=11, Fe/Mn=47) has mosaic extinction indicating shock at 15-50 GPa [2]. In some places, Ol margins are corroded by glass; the glassy veins protrude the olivine grains. The grains are fractured; the fractures are terminated on the grains margins. Locally, large anhedral Ol grains form dense clusters with minor glass. Some of the grains contain tabular chromite inclusions of 100x20 µm in size and angular metal and troilite grains. These features possibly indicate that the clusters are lithoclasts. Px is mostly represented by elongated skeletal crystals of 10-300 µm in length. The smaller Px crystals are more Ca-rich ($En_{47}Wo_{39}$) than the larger ones ($En_{56-62}Wo_{10}$, Fe/Mn=25). Minor Ca-poor Px ($En_{71}Wo_2$, Fe/Mn=27) occurs as large skeletal crystals with rims of $En_{61}Wo_8$. Occasionally, a high-Mg low-Ca Px associates with olivine grains ($En_{79}Wo_1$, Fe/Mn=27). Chromite occurs as irregular grains, needles and fine skeletal crystals within the groundmass. Ca-phosphate (Ph) forms 100 µm-sized anhedral grains localized on the contacts of metal-troilite (Mt-Tr) aggregates with the groundmass and sometimes in the melt pockets which were formed on the margins of Mt-Tr aggregates. Bulk composition of the groundmass (in wt%, defocused beam, 30 nA) is SiO_2 60.3; Al_2O_3 7.64; CaO 7.56; Na_2O 2.52; K_2O 2.16; FeO 6.67; MgO 9.77. Tr (1.9 vol%) occurs as large irregular grains and in association with Mt (1.3 vol%). Tr is granulated suggesting shock pressures up to 40-60 GPa [3]. The mm-sized Mt-Tr aggregates (48 vol% Mt) have globular-like or irregular texture. Mt is a plessitic aggregate of low-Ni phases (Ni 6.65±0.41 wt%, N=5) and taenite (Ni 29.3±1.8, N=4). Fine Mt and Tr inclusions are quite irregularly distributed in the groundmass. The large Mt-Tr aggregates are surrounded by a halo of coarse-grained idiomorphic Ol grains with minor Ph and Gl. The Ol crystals (Fo_{76}) in the halo are less (and in different manner) fractured and significantly more idiomorphic in comparison to that in the rock. The siderophile element composition of the metal, measured by LA-ICP-MS corresponds to unfractionated chondrite metal.

The rock is crossed by centimeters long, 10-20 µm wide silicate melt veins, associated with silicate- and Mt-Tr melt pockets. Modal abundance of shock melts and pockets is 0.8 vol%. Large Tr melt pockets are rich in silicate melt globules. The silicate melt pockets are thickened shock veins and irregular patches of 100-1000 µm in size composed of Gl and mineral fragments that have thin reaction rims on the contacts with Gl. The Gl has a turbulent texture.

The modal mineral composition of NWA 6486 is (vol%): Ol 57.3; Mt 1.32; Tr 2.23; Ph 0.03; Px 8.6; Gl 29.6. A bulk composition of NWA 6486, obtained by XRF is (wt%) Na 0.9; Mg 13.9; Al 1.74; K 0.53; Ca 1.67; Si 22.2; Ti 0.1; Cr 0.4; Fe 15.5; Mn 0.3. An oxygen isotopic composition of acid-washed samples of NWA 6486 is (‰): $\delta^{17}O$ = 3.489±0.13, $\delta^{18}O$ = 4.591±0.22, $\Delta^{17}O$ = 1.103±0.02.

In NWA 6486 the major Ar release is below 1000°C. The three-isotope diagram displays two arrays, indicating the presence of trapped argon with $(^{40}Ar/^{36}Ar)_{trapped}$ ratio of 326±130 (650-800°C) and of -56±140 (880-1040°C). The correction for trapped argon compositions results in plateau ages of 506 ±15 Ma (1σ) and 859±34 Ma (1σ), respectively. Alternatively, the temperature fractions 650-1100°C in isochron plot can be considered as one correlation trend (but with greater scatter) resulting in $(^{40}Ar/^{36}Ar)_{trapped}$ ratio of 514±47 and plateau age of 453±7 Ma (1σ) that assumes one thermal event. K concentration of 0.5217 wt% determined by Ar-Ar dating is identical to XRF K value.

Discussion: The texture, mineral and oxygen isotopic compositions indicate that the NWA 6486 is a quickly crystallized L-chondrite related rock, most possibly of impact origin from some medium-grained precursor rock. The fracturing of Ol indicates that before solidification a mush, consisting of Ol crystals and melt, was compressed. The olivine crystals in the haloes could escape deformation by damping of the Mt-Tr liquid. Mt and Tr contents are 5x less than those of L-chondrites; indicating the segregation of these minerals from the chondrite melt source. Bulk composition of the NWA 6486 is mostly similar to L-chondrites with exception of 1.5xL Na and 6xL K enrichment that is atypical of most L-chondrite melt rocks [1]. We have found so far [1] that there is only one K-rich L-melt rock (Northwest Africa 2981) that could be paired with NWA 6486. Note that high K is mainly a feature of microporphyritic clasts, rarely found in ordinary chondrites (OC) [4, 5]. The NWA 6486 is poorer in K in comparison to the most K-rich OC lithologies and does not display Na-depletion relative to chondrites noted by [4, 6, 7]. The Na/K ratio of NWA 6486 (1.7) is close to that (1.3) of K, Na-rich (14xL and 2.5xL, respectively) microporphyritic clast of Krähenberg LL5 [8]. The bulk composition of NWA 6486 is similar to that of Type IA (olivine porphyritic) chondrule #5, found in Parnallee LL3 [9].

The origin of K-rich objects in chondrites is unclear. Wlotzka et al. [4] explained the formation of K-rich clasts in LL chondrites by selective replacement of Na by K in the solid feldspar due to reaction of regolith with K-bearing impact vapor. However, the NWA 6486 and some OC K-bearing objects [5] are also Na-enriched relatively to OC. Superchondritic Na abundance and subchondritic Na/K ratio together with generally chondritic composition needs some alternative formation mechanism. The isotopic compositions of K, Rb, Ca, Cs in the K-bearing clasts [10] supports the model that K-rich objects in OC could have formed due to impact melting of the mixtures of alkali-rich nebular condensates and chondritic material. However K-rich phases are rare in OC and did not form aggregates large enough for the observed enrichment of melt rocks in K. Selective impact evaporation/condensation processes [11, 12] could also play a role in enrichment of the OC melts by K. The source rock of NWA 6486 could accumulate alkalis by selective condensation of impact vapor into cold regolith traps. The melting of material enriched in alkalis must have occurred in a closed system to prevent evaporation loss of Na and K. Another possibility could be reaction of impact melt with impact vapor in a partially closed system like fractures in the rock. The Na and K have maximum vapor pressures above chondritic melt at 1300°C [13]. The experiment showed [14] that at 1400°C equilibrium saturation of the K-free silicate melt with K-rich gas occurred in 1-2 hr and the K concentration in the melt directly depends of partial pressure of O and K. Note that the experiment was performed under ~10^2x higher partial pressure of K and ~10^8 lower O pressure than in evaporation experiments [13, 15].

Based on this we suggest that the NWA 6486 could have a two-stage impact melting history. In the first stage the L-chondrite was melted and the melt lost alkalis due to evaporation and Mt-Tr liquid was segregated. In the second stage, the rock was remelted and newly melted material together with alkali-rich impact vapor was injected into a partially closed system (fracture) where the saturation of melt preferentially in K had occurred due to selective reaction with vapor. Generally, K-enrichment of OC shock melts noted by [16] could be a consequence of such processes.

A two-stage impact melting history of NWA6486 might be supported by Ar-Ar dating that revealed two events. After formation, NWA 6486 has experienced shock metamorphism on the parent body likely unaffecting the K-Ar system.

Conclusion: We suggest a similarity of NWA 6486 to K-rich inclusions in OCs. Most likely, the rock was formed in two subsequent impact events: 1) shock melting of L-chondrite followed by evaporation of alkalis and segregation of metal; 2) re-melting of the NWA 6486 source ~500 Ma ago and reaction of the melt with chondritic impact vapor enriched in K and Na in a partially closed system, probably in a fracture of the crater basement filled by injected products of the impact. We propose that the K-rich porphyrites could be formed at the contact with vapor in the front end of injecting melt while K-poor ones could represent a body of the melt vein. NWA 6486 likely recorded two recent events on L-chondrite parent body, one of which is in agreement with the ages of many L-chondrites indicating an asteroid breakup event at 470 Ma [e. g., 17].

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