Find of Ureyite- and Jadeite-Bearing Pyroxenes in Chondrules and Matrix of Chelyabinsk LL5 Ordinary Chondrite. N. G. Zinovieva, L. I. Glazovskaya, and P. Yu. Plechov, Department of Petrology, Faculty of Geology, Moscow State University, Leninskiye Gory, Moscow 119991, Russia (nzinov@mail.ru).

Introduction: Ureyite was found in ordinary and carbonaceous chondrites [1-3, and others], and Ramdorh [4] documented aggregates of chromite with plagioclase in chondrules of the Elenovka L5 chondrite and suggested that some of the chromite objects in ordinary chondrites are pseudomorphs after some older minerals (for example, ureyite). We found and described acicular and tabular crystals with exsolution textures, consisting of regularly oriented aggregates of chromite and plagioclase [5-8] in pyroxene-olivine porphyritic chondrules of the Berdyansk L6 and Raguli H3.8 ordinary chondrites. The bulk compositions of the protocrystalline phase correspond to composite of pyroxenes rich in Na-, Cr- and Al (**Berdyansk**: 46 mol % ***Ur***, 9 mol % ***Jd***, 2 mol % ***Di***, 15 mol % ***Ca-Esc***, 28 mol % ***Fe,Mg-Tch***; and **Raguli:** 36 mol % ***Ur***, 15 mol % ***Jd***, 10 mol %, ***Di***, 7 mol % ***Ca-Tch***, 32 mol % ***Fe,Mg-Tch***).

New observations: We found analogous composite pyroxenes in the Chelyabinsk LL5 chondrite, which fell on February 15, 2013, not far from Lake Chebarkul in the Urals, Russia [9, 10, and others]. Figure 1 displays aggregates made up predominantly of Al-bearing (up to 10 wt % Al_2O_3) chromite (white irregularly shaped grains) and plagioclase (dark gray phase between chromite crystals), which is more calcic (***An*** $_{17-22}$) than plagioclase in interstice of the chondrule (***An*** $_{10-15}$). The aggregates are tabular or elongate-tabular, were found in both the chondrules (barred olivine, porphyritic pyroxene-olivine, and pyroxene-plagioclase; Fig. 1a) and the matrix of the chondrite (Fig. 1b), and are pseudomorphs after a protocrystalline phase. The bulk compositions of these pseudomorphs were analyzed by scanning over a certain area by the electron beam and can be readily recalculated into composite pyroxene with various concentrations of the ureyite (***Ur***), jadeite (***Jd***), and diopside (***Di***) end members with the tschermakite components (***Ca-Tch*** and ***Fe,Mg-Tch***). For example, the end-member composition of protocrystalline pyroxene from chondrule C-02n (Fig. 1a) is 34 mol % ***Ur***, 30 mol % ***Jd***, 4 mol % ***Di***, 9 mol % ***Ca-Esc***, 23 mol % ***Fe,Mg-Tch*** and from matrix M-01n (Fig. 1b) - 41 mol % ***Ur***, 17 mol % ***Jd***, 4 mol % ***Di***, 3 mol % ***Ca-Esc***, 30 mol % ***Fe,Mg-Tch***, 6 mol % ***Ca-Tch***.

Results and discussion: The conditions under which the composite Na-Cr-Al pyroxene crystallized in ordinary chondrites can be understood based on the textural relations between this mineral and other minerals in the chondrules in which they were found. In the Chelyabinsk LL5 chondrite, tabular or elongate-tabular crystals of jadeite-ureyite pyroxene were found in three chondrules: barred olivine chondrule (20 × 200 µm at D_{chon} ~600 µm), porphyritic pyroxene-olivine chondrule (20 × 100 µm at D_{chon} ~800 µm), porphyritic pyroxene-olivine-plagioclase chondrule (80 × 300 µm at D_{chon} ~800 µm; Fig. 1a), and in the pyroxene-olivine-plagioclase matrix (Fig. 1b) that cements chondrules of various composition. The crystals of the Na-Cr-Al pyroxene crystallized roughly simultaneously with the phenocrysts of olivine (***Fa*** $_{29-30}$) and orthopyroxene (***Fs*** $_{24-25}$), usually before plagioclase (***Ab*** $_{80-84}$ ***An*** $_{10-15}$ ***Or*** $_{05-06}$) crystallization. In the Berd-

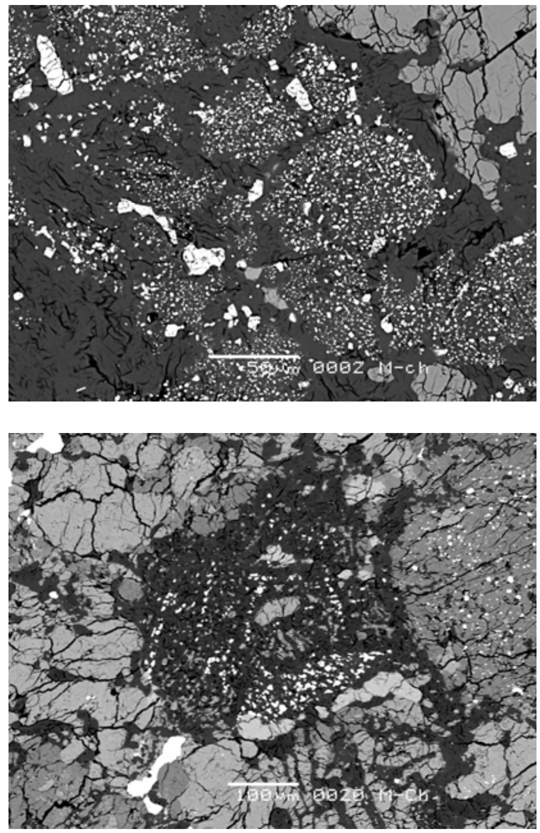

Fig. 1. Cr-spinel - plagioclase pseudomorphs after composite ureyite- and jadeite-bearing pyroxene from a porphyritic olivine-pyroxene-plagioclase chondrule (a, C-02n) and matrix (b, M-01n) of the Chelyabinsk LL5 chondrite (micrographs and chemical analyses were made at the Laboratory of High Spatial Resolution Analytical Techniques, MSU, Faculty of Geology)

yansk L6 chondrite (Figs. 2a, 2b), grains of elongate protocrystalline pyroxene (15 × 200 µm at D_{chon} ~600 µm) started to crystallize either at the boundaries of the chondrule or on large phenocrysts of olivine (***Fa_{25}***) and orthopyroxene (***Fs_{20}***) but are euhedral with respect to the interstitial plagioclase. In the Raguli H3.8

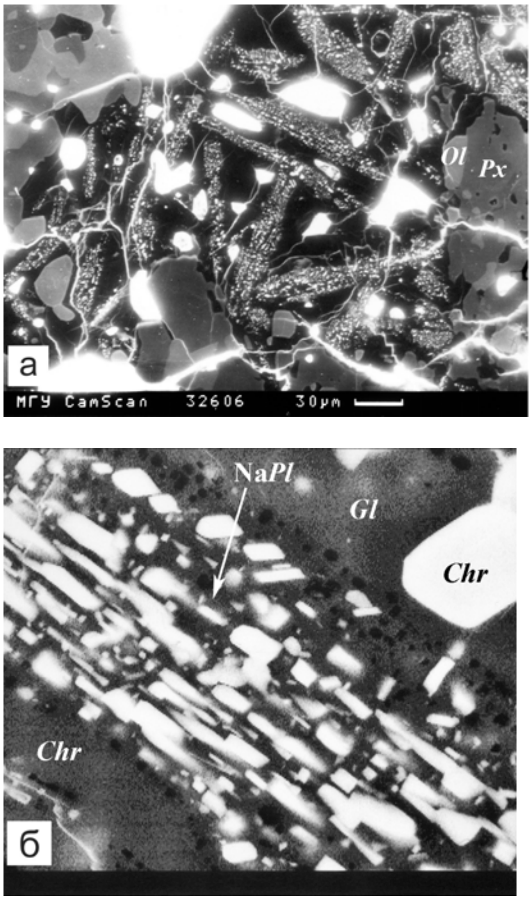

Fig. 2. Cr-spinel - plagioclase pseudomorphs after composite ureyite- and jadeite-bearing pyroxene from a porphyritic pyroxene-olivine chondrule of the Berdyansk L6 chondrite

chondrite, Na-Cr-Al pyroxene develops as relatively large phenocrysts (15 × 30 µm at D_{chon} ~100 µm), which grew inward the chondrule from its boundaries with the matrix, euhedral with olivine beams (***Fa_{18}***) and cemented by feldspar-rich glass (***An_{32} Ab_{67} Or_1*** with minor amounts of normative chromite and ilmenite). This implies that the original Na-Cr-Al pyroxene crystallized in the chondrules from melt roughly simultaneously with or immediately after the crystallization of olivine, usually before the crystallization of plagioclase.

It is known [11-13, and others] that various isomorphic pyroxene series can be enriched in the jadeite end member only under elevated pressures, and the incorporation of the diopside end member into ureyite occurs under pressures above 15 kbar [14].

The pressure under which the relict jadeite-ureyite clinopyroxene crystallized in the chondrules and matrix of the Chelyabinsk LL5 chondrite (calculated by the clinopyroxene barometer [15]) varies within a narrow range of 67-71 kbar (at T = 900ºC) or 65-70 kbar (at T = 1000ºC). These values are close to the pressure values (67-73 kbar at T = 1000ºC) for the crystallization of jadeite-ureyite clinopyroxene in chondrules of the Berdyansk L6 equilibrated chondrite, which were calculated in [16, 17].

Conclusions: The finds of relict grains of jadeite-ureyite clinopyroxene that crystallized from both the chondrule and the matrix melts of the Chelyabinsk LL5 equilibrated chondrite confirm our earlier conclusion [8, 17-21, and others] about a magmatic nature of chondrites and testify that their parent bodies started to crystallize under significant pressures.

Acknowledgments: This work was supported by the Program "Support of Scientific Schools, grant 5877.2012.5". The authors thank the Committee on Meteorites of the Russian Academy of Sciences for providing a sample of Chelyabinsk LL5 chondrite for this study.

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