
LEW 88774 is a monomict ureilite that differs sharply from all other ureilites. The major mineral assemblage is a coarse-grained olivine-opx-cpx-chromite-carbon rock. Silicates and oxygen isotopes are those of Fe-rich ureilites, but the presence and abundance (6%) of chromite, the high pyx/(pyx+ol) ratio (0.9), and the coarsely exsolved pyx are unique. In addition, chromite-carbon reactions produced a new phase near [Fe,Cr]₂C, rare brezinaite (Cr₃S₄), and blades of eskolaite (Cr₂O₃) along chromite rims. Fine-grained interstitial in situ shock melt consists of feldspathic glass, silica, chromite and chromian pyx. The major minerals may be a residua that formed from a Cr-, C-enriched nebular component, at a depth of ~100 bars, by extensive smelting at lower P and pO₂ than that of the ol-pigeonite ureilites. This resulted in the formation of chromite and the reaction of some of the ol to produce more pyx. After extensive burial time, resulting in pyx exsolution, the assemblage was excavated by impact, resulting in in situ shock melting of the interstitial plag (plus some chromite and silicates). Due to the still lower P and pO₂, a second and incomplete phase of reduction took place, due to a rapid cooling rate, resulting in reduction rims on the silicates, and the reaction of the chromite with C to produce [Fe,Cr]₂C and Cr₂O₃.

Introduction. LEW 88774 consists of a major mineral assemblage of 78.8 vol.% large (5mm) pyx crystals with equal amounts of exsolved opx and cpx; lamellae are ~20µm wide, but irregular crystals are also present. These are bounded by olivine (12.1%), chromite (5.8%), and carbon (3.8%), all up to 1mm in size. Olivine, chromite and carbon are also included in pyx. The pyx/(pyx+ol) ratio of 0.9 is greater than that of all other ureilites (0-0.5). Interstitial melt (1.2%) is present along grain boundaries and consists of SiO₂-enriched feldspathic glass and micron-sized grains of chromite plus chromian opx and cpx; tiny crystals of corundum (Al₂O₃) are also present. The margins of the large crystals of chromites and pyx are resorbed, and new chromite and pyx are grown onto them, as are fine symplectitic intergrowths of all of these phases. Large olivine and pyx have reduction rims, and chromites are reduced along chromite-carbon contacts to blades (10µm) of eskolaite (Cr₂O₃). Chromite-carbon reactions also result in forming a new phase (1.3%), near [Fe,Cr]₂C in composition, and rare grains of brezinaite Cr₃S₄.

Mineral Chemistry. The major mineral assemblage is equilibrated, with olivine at F₀₇₄, low-Ca pyx at W₀₄En₇₅, and cpx at W₀₃₃En₁₄. Olivine has a typical ureilite CaO of 0.25%, but "Cr₂O₃" at 0.35% is low. Chromites have compositions that differ from those of all other meteorites. They are zoned by reduction and range from FeCr₂O₄- to MgCr₂O₄- to MgAl₂O₄-rich, with increasing reduction (Fig. 1). Interstitial melt is a quench assemblage that includes mainly feldspathic glass, SiO₂, opx and cpx low in Fe and high in TiO₂ (1%), Al₂O₃ (2-3%), Cr₂O₃ (4-5%), chromite, and skeletal (1µm) crystals of corundum; symplectic intergrowths are too fine to resolve. The [Fe,Cr]₂C phase has (in wt. %) Fe (53-67), Cr (22-33), Ni (0.2-0.8), and C (10-12). Eskolaites have 71-77 Cr₂O₃, 20-26 Al₂O₃, and 3-4 TiO₂.

Discussion. Ureilites are a primitive achondrite group with seemingly irreconcilable chondritic and achondritic characteristics. LEW 88774 presents new aspects to the petrology/geochemistry of this group and thus provides constraints on previous hypotheses as to their origin. The formational history of this ureilite may be divided into three stages.

Stage 1. Nebular Processing. If originally of carbonaceous chondritic parentage, this ureilite would require not only reduction and partial melting, but must be followed by extensive fractional crystallization, to form a pyx- and chromite-rich cumulate. This is difficult to reconcile with oxygen isotopic data [1]. If it is a residua, the assemblage can form from chondritic abundances by reduction and partial melting (smelting with C) only if
the starting material is Cr- and C-enriched. This is necessary in order to provide adequate Cr to form the high chromite content, and provide a higher pO2 than that of the other ureilites so that the chromite is stable. The mg# (74) of this ureilite is lower than that of any other ureilite as a result of the higher pO2. The additional C would make the reaction Fe2SiO4 + C = FeSiO3 + CO proceed further to the right than in other ureilites, resulting in the higher pyx/ol ratio. Krot et al. [2] proposed a nebular scenario involving incomplete evaporation of presolar material to explain chromite-rich chondrules. This type of presolar processing may be required to enhance the initial Cr content because planetary processes would not be adequate without extensive melting and crystal accumulation. Heterogeneity in the starting compositions of ureilites has already been indicated by large isotopic variations, especially in polymict ureilites. Stage 2. Smelting and Equilibration. Smelting relationships were determined by Walker and Grove [3] for the common ol-pigeonite ureilites, which are only slightly different from this Cr-pyx-rich ureilite. These data indicate that LEW 88774 underwent complete equilibration at depth in the ureilite parent body at T ~1200°C, at P ~100 bars, and with pO2 at ~10^-13. The ol-pigeonite ureilites equilibrated at a slightly lower pO2 (~10^-13.5 to 10^-14.5), at which chromite was not stable; they also cooled rapidly after their high T formation, freezing in the pigeonite in most cases. As a result of the extremely slow cooling of LEW 88774 (millions of years) to the conditions described above, chromite was stable, more pyx formed at the expense of some of the olivine, exsolution of pyx to opx and cpx took place, and the texture was equilibrated. Stage 3. Excavation and Reequilibration. The major mineral assemblage of LEW 88774 was excavated by a major impact that resulted in bringing the meteorite closer to the parent body surface. This decompression and increase in T resulted in in situ melting of all of the minor interstitial plag, as well as some of the chromites and silicates, along the grain boundaries. This resulted in the resorbed margins of the chromites and silicates. This interstitial melt was quenched to produce the unusual fine-grained assemblage. The interstitial melt in other ureilites may be of similar origin, rather than trapped liquid. After excavation, the lower P (~ 25 bars), at high T, resulted in a highly reduced state, with a pO2 of ~10^-15. This resulted in incomplete smelting, due to the rapid cooling rate (probably 10-15°C/hr), and produced reduction rims on the olivines and pyx, but also reactions between the chromite and C. This reaction may be expressed as: 2FeCr2O4+6C = 2[Fe,Cr]2C+Cr2O3+5CO. The aluminous eskolaite equilibrated at a T of ~850°C, based on the corundum-eskolaite solvus [4].


Fig. 1. Chromites in LEW 88774, with arrows indicating compositions with increasing reduction.