Introduction: Ureilites are ultramafic (harzburgitic) achondrites composed predominantly of olivine and pyroxenes, abundant carbon (graphites and shock-produced diamonds), some metal and sulfides. These rocks probably represent ultramafic mantles of differentiated parent asteroidal bodies. Age determinations of these rocks by Rb-Sr and Sm-Nd methods have been difficult because of their extremely low abundances of these parent-daughter elements. Nevertheless, Sm-Nd isochron ages were reported for Kenna, Goalpara, MET 78008 and PCA 82506 yielding ages of 3.7±0.02 Ga, ~3.7 Ga, 4.09±0.08 Ga, 4.23±0.06 Ga, respectively [1-4]. These "young" Sm-Nd ages may represent secondary metasomatism events [1] related to impacts [5], as indicated by the similarly young 39Ar/40Ar degassing ages of 3.3-4.1 Ga for ureilites Kenna, Novo Urei and Havero [6]. Alternatively, it has been suggested that these rocks may have been contaminated with terrestrial crustal materials and the isochrons do not have any age significance [2,7]. Indications of old ~4.56 Ga ages for ureilites were reported from the U-Pb and Sm-Nd model ages for MET 78008 [8]. More reliable evidences for old formation ages of ureilites were reported recently using the short-lived chronometers 182Hf-188W, 26Al-26Mg and 53Mn-53Cr. The deficits of 188W in ureilites suggest the metal-silicate segregation occurred very early, ~1-2 Ma after CAI [9]. The 26Al-26Mg and 53Mn-53Cr studies for a feldspathic lithology [10] and the 53Mn-53Cr for olivine- and pyroxene-dominant lithologies [11] in ureilites revealed that they crystallized ~5.4 Ma after CAI, i.e., at 4563.8±0.5 Ma relative to D’Orbigny. In this report, we present Sm-Nd isotopic data for a relatively fresh ureilite, Novo Urei, a rare ureilite fall (1886). We compare these data to Sm-Nd data for other ureilites, and discuss Novo Urei’s petrogenesis.

Samples and Analytical Procedures: Several fragments of Novo Urei weighing 1.67 g were sonicated in ethanol for ten minutes to remove any surface contaminants. The sample was crushed to fine powder. An aliquot of 882 mg was taken as the bulk rock sample (WR). Another aliquot of the bulk rock sample of 793 mg was sonicated first with 2N HCl, then twice with H2O for 10 minutes to eliminate possible post-crystallization, extra- or terrestrial, contamination. The residue, WR(r), weighed 710 mg and leachate, WR(l), weighed 84 mg. All samples were analyzed following the procedures of [12,13].

Sm and Nd abundances: Fig. 1 shows CI-normalized Sm and Nd contents for three bulk rock and leachate samples (red circles) along with the RREE patterns of the bulk rock (green squares) by INAA [14] and four clinopyroxene grains (yellow areas) by ion microprobe [15]. The leachate sample WR(l) contains more Sm and Nd, and is LREE-enriched, as previously demonstrated by acid-leaching experiments [1,16]. Both WR and WR(r) samples contain little or probably no LREE-enriched component, as shown by their LREE-depleted patterns and low Sm abundances. They both lie in the field defined by pure pyroxene grains in the Sm vs 147Sm/144Nd plot (Fig 2). Thus, these Novo Urei bulk rock samples are probably “cleaner” and are better representations of pristine bulk ureilite samples than ureilite ‘finds’ Kenna and Goalpara.

Figure 1. Sm and Nd contents of Novo Urei.

We calculate the Sm and Nd abundances of the melt in equilibrium with the Novo Urei WR from its mineral modes, its Sm and Nd contents, and mineral partition coefficients. The calculation yields a LREE-enriched melt of 147Sm/144Nd=0.13, Sm= 15xCI and Nd=25xCI. This melt could represent the missing basaltic crustal LREE-enriched component complementary to the mafic mantles represented by majority of ureilites.

Sm-Nd isotopic results: Fig. 3 shows 147Sm/144Nd and 143Nd/144Nd data for Novo Urei bulk rocks (red circles). The three samples form a linear array (blue line) corresponding to an age of 4.1±0.1 Ga for λ(147Sm)=0.00654 Ga⁻¹ and initial Nd=+20±2. Both the age and initial Nd are within the ranges

147Sm/144Nd
reported for ureilite “finds”, e.g. Kenna T = 3.74±0.02 Ga and εNd = +3.1 [1]; MET 78008 T = 4.09±0.08 Ga and εNd = +5.3 [3] and PCA 82506 T = 4.23±0.06 Ga and εNd = +13 [4]. The bulk rock sample (open square) plotting above the 4.1 Ga isochron is from a different lab [17]. The 4.56 Ga CHUR isochron (red line) lying below the Novo Urei 4.1 Ga isochron is shown for reference. These two isochrons intersect at 147Sm/144Nd = ~0.51. This highly LREE-depleted component was proposed to be the uncontaminated ultramafic end member of the metasomatic process [1] for both ureilites Kenna and Novo Urei. In this scenario [1], two episodes, i.e. 3.7 Ga for Kenna[1] and 4.1 Ga for Novo Urei [this study], of metasomatism occurred on ureilite parent bodies.

**Petrogenetic model:** The metasomatism model of [1] can be applied to Novo Urei ureilite and is illustrated in its 147Sm/144Nd systematics (Fig 4). The blue open square represents the uncontaminated ureilite mantle source rock. It has 147Sm/144Nd = 0.51 corresponding to 143Nd/144Nd = 0.52135 at T = 4.1 Ga and an assumed very low Nd abundance of ~0.01 ppm. Red open diamonds are two possible LREE-enriched contaminants. One has 147Sm/144Nd = 0.115 and 8 ppm Nd proposed for Kenna in [1] and the other has 147Sm/144Nd = 0.13 and 10 ppm Nd calculated for the melt in equilibrium with the Novo Urei WR. Their respective 143Nd/144Nd ratios are 0.51063 and 0.51104 at 4.1 Ga. Calculations show that it requires only ~0.1% of the LREE-enriched contaminants to match the measured Nd abundance and 143Nd/144Nd for the WR of Novo Urei.

A similar approach uses the 146Sm-142Nd isotopic data for Novo Urei to test this metasomatism model (see Fig. 5). We obtained an 142Nd/144Nd datum only for the WR sample (red circle), which is ε142Nd = +1.5±0.2 ε-units relative to the terrestrial standard. A similar value of ε142Nd = +1.44±0.21 was reported for a pyroxene of 147Sm/144Nd = 0.3395 from MET 78008 [8]. The CHUR (blue star) is ~0.2-ε-units lower than the earth value. The blue curve shows the evolution of ε142Nd over time for the uncontaminated ureilite mantle source having 147Sm/144Nd = 0.51. The red curves are the similar evolution for LREE-rich contaminants having 147Sm/144Nd = 0.115 and 0.13. At 4.1 Ga, the ureilite mantle source has ε142Nd = +3.8 and the respective contaminants have ε142Nd = -1.0 to -1.2. Again, it requires only ~0.1% of such LREE-enrich contaminants to match the measured Novo Urei WR datum at ε142Nd = +1.5. Metasomatism may play a critical role in the interpretation of ureilite isochron data. The robustness of "young" Sm-Nd ages for ureilites should be further tested by studying more recent ureilite falls.