Nephelinization and Metasomatism in the Ordinary Chondrite Parnallee (LL3.6)

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Quick Summary

- CO-like nephelinization of anorthite is present in the OC Parnallee (LL3.6) indicating alkali metasomatism.
- The replaced anorthite appears to be a primary igneous mineral.
- CI is also present in nephelinitized regions indicating the CI was present in the fluid in addition to Na.
- Dissolution lamellae also indicate the action of fluids.

Introduction

- OC Metamorphism shows a characteristic trend from unmetamorphosed petrologic type 3.0 through fully recrystallized type 6. Feldspar within relic chondrules in type 4-6 chondrites is commonly thought to be formed by recrystallization of chondrule mesostasis during metamorphism [1].
- Fluids are not typically considered to play a significant role during the metamorphic process. However, there is evidence for the presence and action of fluids on the OC parent bodies: anorthitic feldspar in LL4 chondrites shows albition and dissolution lamellae [2], and phosphate minerals have properties such as porous textures [3].
- In petrologic type 3.2-3.7 CO chondrites, nepheline is known to replace anorthite within chondrules [4] and refractory inclusions [5], in reactions believed to be the result of alkali metasomatism.
- Nepheline has rarely been described in ordinary chondrites but has been previously identified in LL3.6 Parnallee in an igneous inclusion [6] and in chondrules [7]. However, nepheline identified in these studies occurs in fine grained assemblages which show little relation to the replacement textures seen in CO chondrites.
- We have found CO-like nephelinization textures within chondrules of Parnallee. This adds to the evidence for alkali metasomatism on the LL parent body.

Results

- Nepheline is observed in a texture that indicates anorthite replacement in 5 relit porphyritic olivine-pyroxene chondrules (Chs 1, 3, 4, 5, and 7). The replacement texture appears to be crystallographically controlled and commonly occurs in multiple series of parallel lamellae as well as more massive areas (Fig 1a,b). In Ch3, nephelinization is accompanied by 0.5-1.5 μm diameter silica rich nodules with Fe-bearing pyroxene rims (Fig 1b,c). Some of the anorthite grains show twinning which is preserved in the nephelinitized regions (Fig. 2).
- Three chondrules contain feldspar but no nephelinization (Chs 2, 8, and 9). Ch2 contains fine-grained anorthite and may include minor fine-grained nepheline, but the replacement texture was not seen. In Ch8, anorthite contains dissolution lamellae (Fig. 3a,b) and albition along the edges of the anorthite grains. Feldspar in Ch9 is albite and shows no evidence of alteration.
- WDS analyses give an average feldspar composition of An,Ab, for the unaltered anorthite in all chondrules. Individual analyses overlap phases and show mixing trends to both nepheline and albite (Fig. 4a). In nephelinitized chondrules, the albicic compositions are found near chondrule rims.
- Individual WDS analyses on intergrown anorthite/nepheline material contain up to 3.7 wt.% Cl. A mixing plot of Na₂O vs. Cl possibly indicates the presence of fine-grained sodiumite or manaritic scapolite (Fig. 4b).

Discussion

- Several lines of evidence indicate that anorthitic plagioclase in chondrules within Parnallee is a primary igneous mineral that formed during chondrule formation. Much of the anorthite and nephelinized anorthite occurs as euhedral or subhedral laths and the nepheline replacement, which highlights the crystallographic orientation, indicates twinning (Fig. 2). These features indicate an origin by growth from a melt. In addition, many chondrules in Parnallee still have glassy or only slightly devitrified mesostasis, implying that heating was insufficient to recrystallize glass and form large (tens of μm) anorthite grains.
- Nephelinization textures in Parnallee are very similar to those that have been described in CO chondrites. This includes the lamellar replacement textures and the presence of silica/Fe-bearing pyroxene pyrope-like [4].
- Nephelinization in CO chondrites has been suggested to occur by alteration of anorthite to hydrated nepheline and subsequent dehydration during metamorphism [4]. We propose that a similar process is recorded in Parnallee.
- CI was likely introduced at the same time as the Na, as only Na bearing phases show significant amounts of CI [7] described Na and CI rich chondrule mesostasis in Parnallee but attributed this to an influx of Na and CI during crystallization, rather than enrichment by fluids on the parent body. The bulk CI isotope composition of Parnallee is anomalous among OCs [8] and this may be an indication of unique conditions for this chondrite.
- In addition to nephelinization, the action of fluids is indicated by dissolution lamellae and albition reactions seen in Ch8. In Ch8, dissolution occurs in anorthite that has the same composition as the nephelinitized primary anorthite, suggesting that this chondrule escaped nephelinization but was subject to metasomatism similar to that seen in type 4 OCs [2]. However, the relative timing remains ambiguous due to the absence of dissolution lamellae in any of the nepheline-bearing chondrules.
- Evidence for metasomatism on the OC parent bodies is very clear in anorthite, and may have been overlooked in the past due to the low abundance of primary anorthite present in OCs.
- The source of the fluids is still unknown. A nepheline-bearing clast in Parnallee has negative Δ¹⁸O values [6], indicating the fluids may have originated from carbonaceous chondrite sources. Further work will need to be done in order to identify the source of these metasomatic fluids and to determine how prevalent such reactions were on ordinary chondrite parent bodies.