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Siderophile element patterns, PGE nuggets and vapour condensation effects in Ni-rich quench chromite-bearing microkrystite spherules, ~3.24 Ga S3 impact unit, Barberton greenstone belt, Kaapvaal Craton, South Africa

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Abstract

Energy dispersive spectrometry (EDS), laser ablation inductively coupled plasma mass spectrometry (LA-ICPMS) track analyses of chlorite-dominated quench-textured microkrystite spherules and LA-ICPMS spot analyses of intra-spherule Ni-rich skeletal quench chromites from the 3243±4 Ma Barberton S3 impact fallout unit (lower part of the Mapepe Formation, Fig Tree Group, Barberton greenstone belt, Kaapvaal Craton, South Africa) reveal fractionated siderophile and PGE trace element patterns corresponding to chondrite-contaminated komatiite/basalt compositions. The chlorites, interpreted as altered glass, contain sharp siderophile elements and PGE spikes inherited from decomposed metal and Ni-rich chromite particles. LA-ICPMS spot analysis identifies PGE-rich micronuggets in Ni–chromites (Ir ~12–100 ppm, Os ~9–86 ppm, Ru ~5–43 ppm) and lower levels of the volatile PGEs (Rh ~1–11 ppm, Pd ~0.68–0.96 ppm). Previously reported PGE anomalies in the order of hundreds of ppb in some Barberton microkrystite spherules are accounted for in terms of disintegration of PGE-rich micronuggets. Replacement of the Ni-chromites by sulphide masks primary chondritic patterns and condensation element distribution effects. High refractory/volatile PGE ratios pertain to both the chlorites and the Ni-rich chromites, consistent with similar compositional relations in microkrystite spherules from other impact fallout units in the Barberton greenstone belt and the Pilbara Craton, Western Australia. The near-consistent low Pt/Re and high V/Cr and V/Sc ratios in chlorite of the spherules, relative to komatiites, are suggestive of selective atmospheric condensation of the spherules which favored the relatively more refractory Re and V. Selective condensation may also be supported by depletion in the volatile Yb relative to Sm. Ni–Cr relationships allow estimates of the proportion of precursor crustal and meteoritic components of the spherules. Mass balance calculations based on the iridium flux allow estimates of the order of magnitude of the diameter of the chondritic projectile.

Keywords: Astroid; Impact; Barberton greenstone belt; Microkrystite; Spherule; Platinum group elements; Siderophile elements; Nuggets

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1. Introduction

The identification of chondritic geochemical components in microkrystite spherules of impact fallout/ejecta units constitutes the key for their interpretation in terms of condensation of extraterrestrial impact-released vapour [1–5]. Comprehensive documentation of the S2, S3 and S4 impact fallout units of the Barberton greenstone belt (BGB), eastern Kaapvaal Craton (Fig. 1), reveals a wide range of unique field, petrographic, mineralogical, geochemical and $^{53/52}$Cr and $^{54/52}$Cr isotopic features, allowing identification of extraterrestrial components mixed with volcanic and other detritus [6–11]. Principal criteria for recognition of impact fallout/ejecta units include: (1) the units can be correlated in below-wave base environments between basins and sub-basins independently of facies variations of the host sediments [6,10]; (2) the units are commonly overlain by tsunami-generated high energy deposits; (3) microkrystite spherules display inward-radiating quench textures and centrally offset vesicles (Fig. 2), representing their original glassy and airborne dynamic nature, as distinct from outward-radiating textures of volcanic varioles commonly cored by microphenocrysts of feldspar and quartz [4]; (4) Microkrystites may contain quench-textured Ni-rich chromites with high Co, Zn and V abundances, which are unknown in terrestrial chromites [8]; (5) Microkrystites may contain Ni-rich and PGE-rich micronuggets [4,7,12].

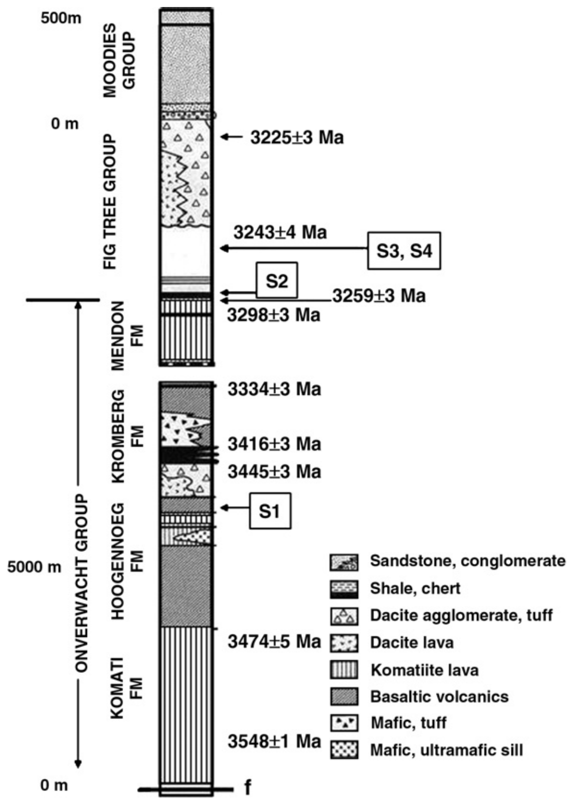

Fig. 1. Schematic stratigraphic columnar section of the Barberton greenstone belt, including location of microkrystite spherule units (after [8,10]).

Byerly and Lowe (1994) [8] documented octahedral, skeletal and feather-like quench-textured Ni-rich chromites within the S3 impact ejecta unit (Fig. 3), including very high Ni levels (NiO < 23.44%) and in some varieties high Co, Zn and V levels. These Ni–chromites are distinct from terrestrial-type Ni–chromites associated with sulphide (NiO < 0.3%) [13,14], and have lower Fe2O3/FeO ratios than K–T boundary microkrystite spherules, attributed to condensation under low-oxygen Archaean atmospheric conditions. From spherule size distribution (mean 0.85 mm) and the iridium flux (5.3 mg/cm^2) Byerly and Lowe [8] deduce a 20–30 km-diameter of the parental asteroid.

In the present study we focus on sample SA306-1 from the S3 impact ejecta unit (Jay Chert: 31°01.137″ E 25°54.908″ S) — a well preserved microkrystite spherule-rich rock provided by G.R. Byerly, and analyzed by Scanning Electron Microscopy (SEM) (analyst A.Y. Glikson) and laser ablation ICPMS (LA-ICPMS) (analysts: C. Allen, W. Taylor). The spherules are dominated by quench-textured microcrystalline aggregates of chlorite and chlorite–quartz aggregates, and contain centrally offset vesicles (Fig. 2A), quench textures (Fig. 2D) and Ni-rich skeletal octahedral chromites (Fig. 3C,D). Inward-radiating quench textures, diagnostic of microkrystite spherules, are manifest (Fig. 2B,C). The inter-spherule matrix contains irregular fragments of mafic volcanic rock and possibly tektites. Sample SA315-5 (Princeton Tunnel: 30°58.972″ E 25°49.967″ S) contains needle-like crystallites probably representing altered pyroxene and olivine (Fig. 2D). SEM images display resorption of inner spherule regions by siliceous material (Fig. 3A) and concentric patterns of chromite and sulphide grains. As distinct from late Archaean impact ejecta units in the Pilbara Craton, Western Australia [4,12,15–17], the Barberton spherules contain little or no K-feldspar.

2. Analytical methods

Scanning Electron Microscopy (SEM) and Energy Dispersive Spectrometric (EDS) analyses were conducted by A.Y. Glikson on a Jeol-6400 at the Research School of Biological Studies, Australian National University. Procedures commenced with semi-quantitative X-ray mapping at mm-scale, proceeding with accurate point analyses of element abundances at