Ni-Rich Cr Spinels in Spherule Beds from the Barberton Mountain Land (South Africa) are of Terrestrial Origin: Evidence Against Impact Origin of Spherule Layers.

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Introduction and Summary. A number of distinct spherule layers have been found in the Barberton Greenstone Belt, Eastern Transvaal, South Africa. These spherule layers have been interpreted by Lowe and co-workers [1-3] as deposits resulting from large-scale Precambrian impacts, about 3.2 Ga ago. Their arguments were largely based on petrological and geochemical analyses, showing quench textures and high abundances of siderophile elements (of which some show chondritic proportions). A recent detailed mineralogical, petrological, and geochemical study [4] pointed out that there are numerous difficulties with the impact model for the Barberton spherule beds. Nevertheless, Byerly and Lowe [5] described unusual Ni-chromites from some of the Barberton spherules, which they regard as being derived from the impacting bolide and thus interpreted as further proof of an impact origin of the spherule beds. We have found similar Ni-rich Cr-spinels in samples from several other spherule bed localities. Some of our analyses show also high Ni contents and compositions similar to those found by [5]. However, calculations of the Fe^{3+}/Fe(total) ratio based on spinel stoichiometry, following the method used by Robin et al. [6] for cosmic and terrestrial spinels, yield low ratios. The ratios vary between about 28 and 65, with a maximum between 40 and 55. Practically all spinels derived from extraterrestrial matter have ratios larger than 65; spinels found at the K-T boundary typically have ratios between 80 and 99. The low Fe^{3+}/Fe(total) ratios observed in the Barberton Cr-spinels are more typical for spinels formed in magmatic processes [6] and can therefore not be used to support an impact model for the Barberton spherule layers.

Sample Descriptions. For [4,7] and for this study, drill core specimens from Princeton and Mount Morgan mines and hand specimens from underground exposures at the Princeton and Sheba gold mines, all near Barberton, and two samples from the type surface exposure [2] were analyzed in order to compare specimens from heavily sulfide- (and gold-) mineralized settings in gold mines with samples from a less mineralized locality. The samples are thought to represent either the S2 (BA-2,3,4 from Sheba mine) and S3 or S4 (Princeton, Mt.Morgan mines) spherule beds [2]. In the present study, we concentrated on samples from the Sheba locality. Sheba sample BA-2 originates from Fig Tree metasediments just south of the Birthday Anticline, while samples BA-3 and -4 were associated with tightly infolded Onverwacht strata oriented parallel to the Sheba Fault in crosscut 6 in Sheba Mine, to the west of the Birthday Anticline. The Sheba samples most likely represent the S2 layer at the contact between Fig Tree and Moodies Group. All our samples are completely converted to assemblages of secondary minerals, the products of hydrothermal alteration. Major mineral constituents are quartz, siderite, sericite, and pyrite. Underground, drillcore and surface samples all have similar mineralogical compositions. Individual samples from the Sheba gold mine and from the surface exposure contain more silica in the matrix between spherules - at the expense of siderite and sericite proportions. Some of these samples are heavily transected by chert bands. Minor minerals are sphalerite, occasionally baryte, chalcopyrite, and apatite, as well as some clay minerals (biotite, muscovite or montmorillonite). Important trace minerals are gersdorffite that was observed nearly in every sample, less abundant chrome-spinel, a Zn-Cu-Sb-sulfide (probably a Fahlore mineral, such as Zn-rich tetrahedrite), and occasionally arsenopyrite and rutile.

Chemistry of Ni-Rich Cr-Spinel. The occurrence of unusual Ni-chromites in Barberton spherule samples was first described Byerly and Lowe [5]. They concluded that the high Ni contents resulted mainly from the impacting bolide and were further evidence for an impact origin of the spherule beds. We have also found some Ni-rich chromites in various samples from different spherule bed localities. Detailed electron microprobe analyses were performed (see, e.g., Table 1 for some typical results; more analyses are given in [7]) and have shown that their compositions are, in general, similar to those reported by [5] (see also Table 1). However, besides Ni-rich chromite, other spinel phases with Zn and Ni, or Zn and Fe are present in these samples. This leads to the question whether these chromites represent primary or secondary phases. We have repeatedly observed intergrowths of chromite and gersdorffite, with or without chalcopyrite. These phases occur not only in spherules, but also in the matrix of spherule beds. Furthermore, we have recalculated the Fe^{3+}/Fe(total) ratios in the spinels from stoichiometry, following the method of Robin et al. [6]. These authors presented a detailed study of spinel chemistry and oxidation state of terrestrial and extraterrestrial spinels and found that all extraterrestrial spinels have Fe^{3+}/Fe(total) ratios larger than about 65 (Fig. 1), while terrestrial spinels have, in general, much lower ratios. Using the same procedure as [6], we find that the Barberton spinels have low ratios (Fig. 1), inconsistent with an extraterrestrial origin. Their low modal abundance and the low Fe^{3+}/Fe(total) ratios are more characteristic of conditions typical of magmatic processes.

ACKNOWLEDGEMENTS: We are grateful to E. Robin (CEA-CNRS, Orsay, France) for help with the calculations and detailed discussions; and to Anglovaal Ltd. (Barberton) for samples and logistical support.

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TABLE 1. SELECTED ELECTRON MICROPROBE ANALYSES OF NI-RICH CR-SPINELS FROM VARIOUS BARBERTON SPHERULE SAMPLES AND STOICHIOMETRICALLY CALCULATED FE^{3+}/FE(TOTAL) RATIOS.

	BA2Cr1	BA2Cr7	BA2Cr9	BA2Cr10	BA3Cr1	BA3Cr2	BA3Cr3	BA3Cr4	105-12-R*	294-1-C*	294-1-C*
Weight(%)											
MgO	0.42	2.89	1.03	2.18	0.87	0.87	0.82	0.85	0.37	1.56	1.58
Al_2O_3	1.32	7.24	6.14	6.29	0.45	0.47	0.43	0.45	1.24	0.17	2.16
TiO_2	0.10	0.60	0.32	1.03	0.08	0.10	0.09	0.10	0.06	0.09	0.12
Cr_2O_3	34.00	39.04	37.67	39.90	51.22	50.34	49.76	48.95	50.56	53.11	48.17
MnO	0.04	0.10	0.03	0.01	0.04	0.07	0.08	0.09	0.44	2.01	1.69
FeO	40.84	32.04	35.52	29.56	28.87	29.17	30.21	30.57	27.67	25.87	23.62
Co	0.31	0.28	0.29	0.31	0.34	0.33	0.31	0.36	0.23	0.30	0.243
NiO	15.45	0.40	14.59	1.13	13.73	12.97	13.04	12.21	10.40	12.02	11.24
Total	92.47	82.59	95.60	80.41	95.59	94.31	94.73	93.57	90.97	95.13	88.82
Fe^{3+}	0.984	0.327	0.655	0.245	0.441	0.446	0.476	0.483	0.334	0.390	0.352
Fe^{2+}	0.534	0.845	0.545	0.868	0.543	0.562	0.567	0.586	0.644	0.487	0.492
Fe^{3+}/Fe(t)	64.812	27.891	54.555	22.041	44.830	44.267	45.641	45.195	34.179	44.440	41.667

*Wt%-analyses taken, for comparison, from Byerly and Lowe [5]; sample numbers are theirs.

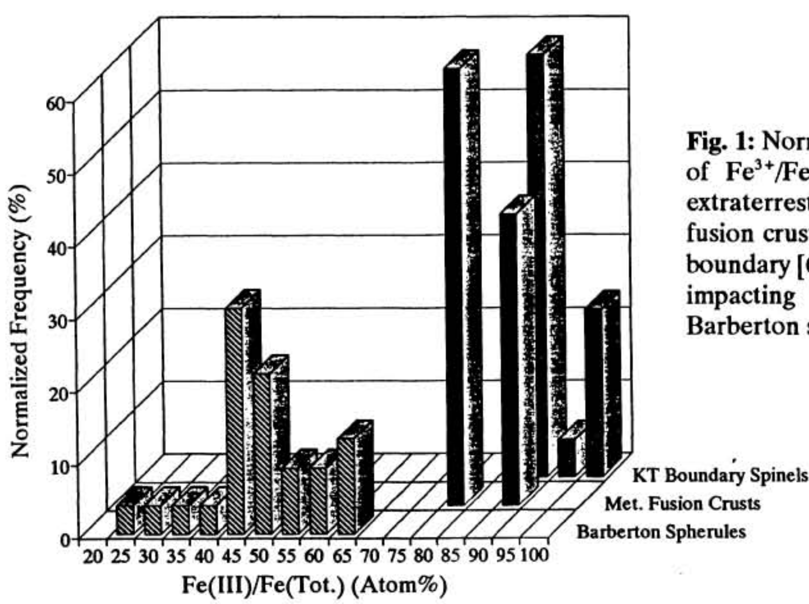

Fig. 1: Normalized frequency (to 100%) of Fe^{3+}/Fe(total) ratios in spinels of extraterrestrial origin (from meteorite fusion crusts [6]), spinels from the K-T boundary [6] (which originated from the impacting bolide), and spinels from Barberton spherule samples.