EARLY ARCHEAN SPHERULE BEDS OF POSSIBLE IMPACT ORIGIN FROM BARBERTON, SOUTH AFRICA: A DETAILED MINERALOGICAL AND GEOCHEMICAL STUDY. Christian Koeberl[1], Wolf Uwe Reimold[2], and Rudolf H. Boer[2], [1]Institute of Geochemistry, University of Vienna, Dr.-Karl-Lueger-Ring 1, A-1010 Vienna, Austria, [2]Economic Geology Research Unit, University of the Witwatersrand, P.O. Wits, Johannesburg 2050, South Africa.

The Barberton Greenstone belt is a 3.5- to 3.2-Ga-old formation situated in the Swaziland Supergroup near Barberton, northeast Transvaal, South Africa. The belt includes a lower, predominantly volcanic sequence, and an upper sedimentary sequence (e.g., the Fig Tree Group). Within this upper sedimentary sequence, Lowe and Byerly [1] identified a series of different beds of spherules with diameters of around 0.5–2 mm. Lowe and Byerly [1] and Lowe et al. [2] have interpreted these spherules to be condensates of rock vapor produced by large meteorite impacts in the early Archean. This interesting hypothesis is based mainly on the structure of the spherules, which is reported to be similar to quench structures, and on the discovery of Ir anomalies of up to several hundred ppb in some of the spherule beds [2]. Although Lowe et al. [2] reported the abundances of the platinum group elements (PGEs) to be of roughly chondritic proportions, a more detailed study by Kyte et al. [3] showed that the PGEs are fractionated relative to the chondritic abundances. They interpreted this to be due to later hydrothermal alterations.

The study of impacts early in the history of the Earth is of great importance and interest; we feel that therefore a more detailed investigation of the Barberton spherule beds is warranted, especially because no detailed mineralogical study of the spherules (and of all secondary mineralizations such as abundant sulfide mineralization) and no detailed geochemical stratigraphy (including, e.g., the rare earth elements) is available so far. The host phase of the Ir (and PGE) anomaly is also unknown.

We have collected a series of samples from drill cores from the Mt. Morgan and Princeton sections near Barberton, as well as samples taken from underground exposures in the Sheba and Agnes mines. These samples seem much better preserved than the surface samples described by Lowe and Byerly [1] and Lowe et al. [2]. Over a scale of just under 30 cm, several well-defined spherule beds are visible, interspaced with shales and/or layers of banded iron formation. Some spherules have clearly been deposited on top of a sedimentary unit because the shale layer shows indentions from the overlying spherules. Although fresher than the surface samples (e.g., spherule bed S-2), there is abundant evidence for extensive alteration, presumably by hydrothermal processes. In some sections of the cores sulfide mineralization is common.

For our mineralogical and petrographical studies we have prepared detailed thin sections of all core and underground samples (as well as some surface samples from the S-2 layer for comparison). For geochemical work, layers with thicknesses in the order of 1–5 mm were separated from selected core and underground samples. The chemical analyses are being performed using neutron activation analysis in order to obtain data for about 35 trace elements in each sample. Major elements are being determined by XRF and plasma spectrometry. To clarify the history of the sulfide mineralization, sulfur isotopic compositions are being determined. We hope to be able to identify the host phase of the platinum metal anomaly by separating spherules and matrix. At the time of the conference we will report on the first geochemical and mineralogical results and their bearing on the impact hypothesis.

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U-Pb ISOTOPIC RESULTS FOR SINGLE SHOCKED AND POLYCRYSTALLINE ZIRCONS RECORD 550–65.5-Ma AGES FOR A K-T TARGET SITE AND 2700–1850-Ma AGES FOR THE SUDBURY IMPACT EVENT. T. E. Krogh[1], S. L. Kamo[1], and B. F. Bohor[2], [1]Jack Satterly Geochronology Department, Royal Ontario Museum, 100 Queen's Park, Toronto, Ontario, M5S 2C6, Canada, [2]U.S. Geological Survey, Box 26046, MS 972, Denver CO 80225, USA.

The refractory mineral zircon develops distinct morphological features during shock metamorphism and retains these features under conditions that would anneal them in other minerals. In addition, weakly shocked zircon grains give primary ages for the impact site, while highly reconstituted (polycrystalline) single grains give ages that approach the age of the impact event. Data for a series of originally coeval grains will define a mixing line that gives both of these ages providing that no subsequent geological disturbances have overprinted the isotopic systematics. In this study, we have shown that the three zircon grain types described by Bohor (this session), from both K-T distal ejecta (Fireball layer, Raton Basin, Colorado) and the Onaping Formation, represent a progressive increase in impact-related morphological change that coincides with a progressive increase in isotopic resetting in zircons from the ejecta and basement rocks. Unshocked grains are least affected by isotopic resetting while polycrystalline grains are most affected.

U-Pb isotopic results for 12 of 14 single zircon grains from the Fireball layer (Fig. 1) plot on or close to a line recording a primary age of 550 ± 10 Ma and a secondary age of 65.5 ± 3 Ma. Data for the least and most shocked grains plot closest to the primary and secondary ages respectively. The two other grains each give ages between 300 and 350 Ma. This implies that the target ejecta was

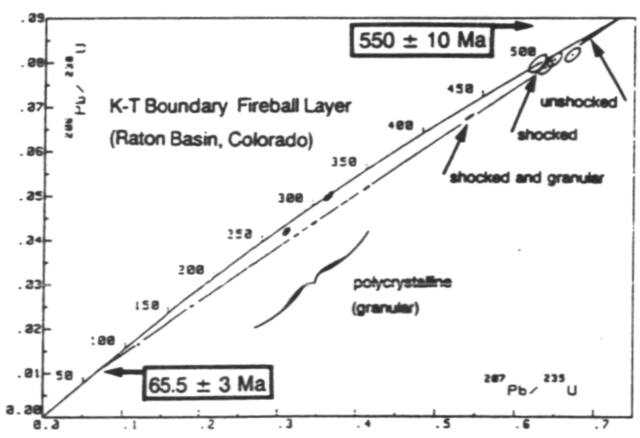

Fig. 1. U-Pb data for single zircons from the K-T boundary fireball Layer, Raton Basin, Colorado.

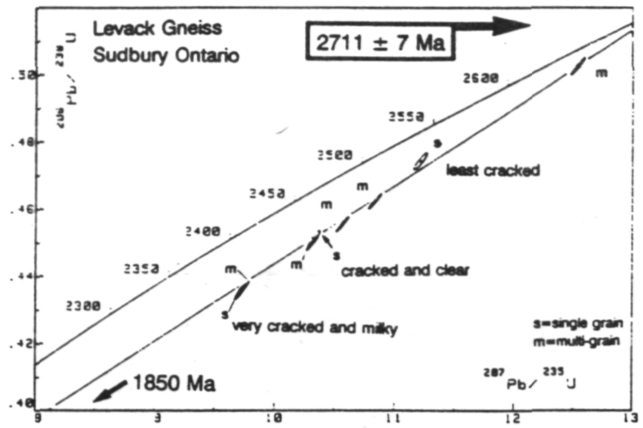

Fig. 2. U-Pb data for single zircons and multiple zircon fractions from the Levack gneiss, Sudbury, Ontario.

dominated by 550-Ma rocks and that the recrystallization features of the zircon were superimposed during the impact event at 65.5 Ma.

Data for four of the five polycrystalline grains are colinear (33% probability of fit), with data displaced 49%, 58%, 62%, and 82% from 559 ± 5 Ma toward the younger event and provide the best age estimate for the impact event (65.5 ± 3 Ma). Data for three colinear points (66% probability of fit), which are represented by an unshocked, a shocked, and a shocked and granular grain, are displaced by only 3%, 12%, and 26% respectively toward the younger event, thus providing the best estimate for a primary age of 544 ± 5 Ma. Since there is no reason to assume that single unrelated grains should form colinear arrays within our small (±4 m.y.) uncertainty, this coincidence implies that these grains share the same primary and secondary ages. The two different upper intercept ages indicate that the most and least shocked grains may have come from different parts of the impact site. Considering a possible 180-km impact site, ejecta from a local focused area may be inferred.

A predominant age of 550 Ma for zircons from the Fireball layer provides an excellent opportunity to identify the impact site and to test the hypothesis that multiple impacts occurred at this time. A volcanic origin for the Fireball layer is ruled out by shock-related morphological changes in zircon and the fact that the least shocked grains are old.

Basement Levack gneisses north of the Sudbury structure have a primary age of 2711 Ma. Data for three single zircons from this rock (Fig. 2), which record a progressive increase in shock features, are displaced 24%, 36%, and 45% along a Pb-loss line toward the 1850 ± 1 Ma minimum age for the impact as defined by the age of the norite. Southeast of the structure three shocked grains from the Murray granite record a primary age of 2468 Ma and are displaced 24%, 41%, and 56% toward the 1853 ± 4 Ma event as defined by coexisting titanite. The coincidence of titanite and norite ages, however, is consistent with near coeval impact and intrusion. The correlation of discordance with the intensity of shock-related features implies that the impact caused the observed discordance, but the precise age of impact is not evident from zircon data since some recent lead loss has occurred.

Data for five of six single unshocked zircons from a fluidal glass sample from the North Range Gray Onaping Formation plot directly on the concordia curve and give ages of 2719 Ma, 2708 Ma, 2696 Ma, 2686 Ma, and 2678 Ma; the sixth data point is 2679 Ma (2.2% discordant). These ages reflect the age spectra of the nearby Archean basement. A volcanic origin at 1850 Ma is impossible since the zircons would have to be 100% xenocrystic in origin and this has never been observed in volcanic rocks.

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INFLUENCE OF THE PRESHOCK TEMPERATURE ON SHOCK EFFECTS IN QUARTZ. F. Langenhorst and A. Deutsch, Institut für Planetologie, Wilhelm-Klemm-Str. 10, D-4400 Münster, Germany.

Shock metamorphic features are the prime indicators for recognizing impact phenomena on Earth and other planetary bodies [1,2]. In the past, many shock-loading experiments were performed at room temperature [3–5] in order to artificially reproduce shock effects occurring in nature. Results of such experiments have been extensively used as a database for shock wave barometry of impact-metamorphosed terrestrial and extraterrestrial rocks. Although the pressure dependence of shock features is well known, information about the influence of the preshock temperature is almost lacking (except [6–8]). Especially in the case of large-scale impacts like Sudbury, it is expected that deep-seated crustal rocks were subjected to shock at elevated temperatures.

Therefore, we continued to perform shock experiments at elevated temperatures on <0.5-mm thin disks of single crystal quartz cut parallel to the {1010} face [8]. These specimens were shocked at pressures from 20 to 50 GPa (precision <±3%) and preshock temperatures of 20°C, 540°C, and 630°C ± 5°C using a previously described high-explosive device [9]. The preshock temperature of 630°C clearly exceeds 573°C, the α/β-transition temperature, whereas the preshock temperature of 540°C is just below the transition temperature. All recovered quartz samples were investigated by universal stage, spindle stage, and a newly developed density gradient technique. Errors of refractive index and density measurements are ±0.0005 and ±0.002 g/cm³ respectively.

Orientation of Planar Deformation Features (PDF) (Figs. 1a,b): The frequency distribution of PDF in quartz shocked at 20 GPa and 540°C displays two maxima at {1013} and {1011}, which are quite typical for this pressure as already known from naturally [10,11] and experimentally [4] shocked quartz. In contrast, PDF in quartz shocked at 20 GPa and 630°C show a broad distribution of crystallographic orientations with indistinct maxima that are difficult to index. In particular, the total absence of {1013} orientations is most characteristic for this preshock temperature. This difference in orientation of PDF in quartz heated to 540°C and 630°C and both shocked to the same peak pressure may reflect the slight difference in the lattices of α and β quartz.

Refractive Index Data (Fig. 2): Drastic differences of the optical parameters of quartz shocked at the three different preshock temperatures appear between 25 GPa and 40 GPa. Refractive indices of quartz shocked at 540°C and 630°C decrease drastically and discontinuously in the pressure range from 25 to 26 GPa and from 25 to 27.5 GPa respectively, whereas refractive indices of cold shocked quartz change smoothly and continuously from 25 to 35 GPa [12,13].

Density Data (Fig. 3): The densities determined with a so-called density gradient column confirm the results of the refractivity measurements. An abrupt decrease of densities for quartz shocked at 540°C and 630°C takes place between 25 and 26 GPa, whereas quartz shocked at room temperature shows the equivalent change in the pressure range from 25 to >34 GPa.