AN ORDINARY CHONDRITE IMPACTOR COMPOSITION FOR THE BOSUMTWI IMPACT STRUCTURE, GHANA, WEST AFRICA: DISCUSSION OF SIDEROPHILE ELEMENT CONTENTS AND OS AND CR ISOTOPE DATA.

Christian Koeberl[1], Alex Shukolyukov[2], and Günter Lugmair[2,3]. [1]Department of Geological Sciences, University of Vienna, Althanstrasse 14, A-1090 Vienna, Austria (christian.koeberl@univie.ac.at); [2]Scripps Institution of Oceanography, University of California, San Diego, La Jolla, CA 92093-0212, U.S.A. (ashukolyukov@ucsd.edu); [3]Max-Planck-Institute for Chemistry, Cosmochemistry, P.O. Box 3060, D-55020 Mainz, Germany (lugmair@mpch-mainz.mpg.de).

Summary. Osmium isotope data had shown that Ivory Coast tektites contain an extraterrestrial component, but do not allow distinction between chondritic and iron meteorite contamination. PGE abundances of Ivory Coast tektites and impactites and target rocks from the Bosumtwi crater, the source crater of the Ivory Coast tektites, were all relatively high and did not allow to resolve the presence, or identify the nature, of the meteoritic component. However, Cr isotope analyses of an Ivory Coast tektite yielded a distinct ^{53}Cr excess of 0.30±0.06 ε, which indicates that the Bosumtwi impactor was an ordinary chondrite.

Introduction. The Bosumtwi impact crater is located in the Ashanti Province of Ghana, near the town of Kumasi, centered at 06°32'N and 01°25'W. The structure, which has an age of 1.07 Million years, is almost completely filled by Lake Bosumtwi and has a rim-to-rim diameter of about 10.5 km. The first suggestions that the Bosumtwi crater is the source crater for the Ivory Coast tektites were made in the early 1960s. Ivory Coast tektites were first reported in 1934 from a geographically rather restricted area in the Ivory Coast (Cote d'Ivoire), West Africa. Microtektites were reported from deep-sea sediments of corresponding age from the eastern equatorial Atlantic Ocean west of Africa. Ivory Coast tektites and the Bosumtwi crater have the same age [1], and there are close similarities between the isotopic and chemical compositions of the tektites and crater rocks [1,2]. These observations strongly support a connection between the crater and the tektites.

This makes the Bosumtwi crater one of only three impact structures that have been identified as source craters of a tektite strewn field. Strewn fields are usually defined based on the geographic distribution of microtektites (in deep sea cores) and tektites (on land). All tektites represent distal ejecta. Besides tektites, there are several other distal ejecta layers known in the geological record. Some, such as the K/T boundary ejecta layer, are associated with significant siderophile element anomalies, which are thought to represent an extraterrestrial (meteoritic) contribution. On the other hand, none of the tektite strewn fields seem to be associated with a significant meteoritic component, except for a minor Ir anomaly in a microtektite-bearing layer from the Australasian strewn field.

A Meteoritic Component? Os Isotope Data. Ivory Coast tektites were found by Palme et al. [3] to have high contents of Ir, Os, and other siderophile elements, which they interpreted as evidence of a meteoritic component. However, Jones [4] noted that the high siderophile element contents in the tektites could be the result of high indigenous contents in the Bosumtwi target rocks due to local mineralization. The question regarding the presence of a meteoritic component in Ivory Coast tektites was only resolved in a Re-Os isotopic study by Koeberl and Shirey [5], who found a distinct meteoritic component (≤0.6%, chondritic composition) in Ivory Coast tektites (and a smaller one in impact glasses from the Bosumtwi crater). They also found that some samples of the target rocks had elevated contents of the siderophile elements (e.g., Os), but that the Os isotopic signature in these samples was terrestrial, in contrast to the clear extraterrestrial Os component in Ivory Coast tektites and glassy fractions from suevites. [5].

Siderophile Element Compositions. Subsequently, we tried to compare the meteoritic component found in the tektites with the siderophile element anomalies in the target rocks and impact breccias at the Bosumtwi crater. In 1997 and 1999 representative samples of impact breccias and target rocks were collected from the Bosumtwi impact crater to conduct the petrographic, geochemical and paleomagnetic studies. Major and trace elemental composition as well as the platinum group element (PGE) abundances were analyzed in the selective target rocks (including shale, graywacke and two different types of granites) and suevite-derived impact glass samples. Major elements were determined by X-ray fluorescence spectrometry analysis (XRF), and trace elements (except the PGEs) by instrumental neutron activation analysis (INAA). The PGEs were measured by ICP-MS after NiS fire assay and by NAA after an anion resin preconcentration procedure. Preliminary data were reported by [6].

Our data [6, and in preparation] show elevated Ru, Pd, Os, Ir and Ag contents in impact glasses, which, on first glance, suggest the presence of a meteoritic contribution. However, the target rocks also have rather high PGE abundances, so that a significant difference between the abundances of these two groups of samples is not obvious. The CI-chondrite-normalized abundances of PGEs, Au, Ag and Re, for Bosumtwi target rocks and impactites show high and variable Au and Pt abundances in both target rocks and impactites. Thus, the relatively high values of regionally occurring lithologies could very well result from the fact that the Bosumtwi crater is located in an area known for its widespread gold mineralization, as already recognized by [4, 5]. Highly variable and high Au contents were also determined by a number of earlier workers in Bosumtwi target rocks [2, 4,] and Ivory Coast tektites [1]. Thus, comparison of the indigenous abundances of PGE in the target rocks with PGE abundances in impactite samples does not allow to unambiguously identify a meteoritic component in the impact breccias.

Cr Isotopic Compositions. Although the PGE abundances in the tektites and in the Bosumtwi impact breccias did not yield any information regarding the exact nature of the impactor at Bosumtwi, the Os isotopic data have clearly shown the presence of some meteoritic component in the tektites and impact glasses. However, Os isotope data do not allow the distinction between a chondritic and an iron meteorite component. Nevertheless, enrichments in Cr (besides Co and Ni) in the tektites compared to the Bosumtwi target rocks indicated that the impactor had more likely been a chondritic meteorite rather than an iron meteorite [2]. Thus, a Cr isotopic study was considered promising [7]. Studies of the ^{53}Mn-^{53}Cr isotope systematics [8] have shown that most meteorite classes are characterized by a variable excess of ^{53}Cr relative to terrestrial samples. This reflects an early Mn/Cr fractionation and/or possibly heterogeneous distribution of the now-extinct parent radionuclide ^{53}Mn ($T_{1/2}$ = 3.7 Ma). Regardless of the scenario, the observed difference in ^{53}Cr/^{52}Cr ratios between Earth and meteorites represents a direct experimental fact that does not involve any models or assumptions. This permits to unequivocally demonstrate an extraterrestrial component in geological samples on Earth that contain a significant proportion of meteoritic Cr, based on measurements of the Cr isotopic composition (e.g. [9]). The isotopic variations are measured as the deviations of the ^{53}Cr/^{52}Cr ratios from the standard terrestrial ^{53}Cr/^{52}Cr ratio, which are expressed in ε-units (1 ε is 1 part in 10^4, or 0.01%). Thus, by definition, the standard terrestrial ^{53}Cr/^{52}Cr is ≡0 ε. In contrast to most of the meteorite classes, the bulk samples of carbonaceous chondrites also show an excess of ^{54}Cr due to the presence of a pre-solar component (e.g., [10]). To obtain the required high precision we use a second order mass fractionation correction based on the ^{54}Cr/^{52}Cr ratio [8], which, for this purpose, is assumed to be normal. Thus, an elevated ^{54}Cr/^{52}Cr ratio in carbonaceous chondrites translates into apparent *deficit* of ^{53}Cr [9]. This permits to distinguish carbonaceous chondrites from the other meteorite classes.

Here we applied the Cr isotope method for the detection of an extraterrestrial component in an aliquot of Ivory Coast tektite IVC-3395 (the same samples had yielded a meteoritic Os isotope signal, [5]). The chemical and mass-spectrometric procedures were similar to those described in [8]. We found a distinct ^{53}Cr excess of 0.30±0.06 ε (uncertainty is $2\sigma_{mean}$). This value was obtained by repeat measurements of the Cr isotopic composition: 22 runs (300 ratios each). The result unequivocally confirms the presence of an extraterrestrial component. The data also show that a carbonaceous chondrite type projectile can be excluded: as noted above, carbonaceous chondrites have an apparent deficit of ^{54}Cr. An enstatite chondrite type projectile can also be excluded because their characteristic ^{53}Cr/^{52}Cr ratio is significantly smaller, ~0.17 ε [9]. Thus, the most likely projectile is an ordinary chondrite type body. Ordinary chondrites have an average ^{53}Cr excess of ~0.48 ε [8]. The somewhat lower ^{53}Cr excess in IVC-3395 probably results from the presence of a normal terrestrial chromium component. Thus, the cosmic Cr in IVC-3395 would be ~63% or 150 ppm of the measured Cr concentration in IVC-3395 of 240 ppm. The Cr concentration in all classes of the ordinary chondrites is essentially the same: ~3740 ppm [11]. Therefore, based on the cosmic Cr concentration in IVC-3395 (and taking into account the uncertainty in the ^{53}Cr/^{52}Cr ratio) we calculate that this tektite incorporated 3-5% of an ordinary chondrite component.

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