METEORITIC IRON IN JAVANESE KRIS DAGGERS: A COMPARATIVE XRF STUDY PERFORMED ON ORIGINAL DAGGERS AND NEWLY FORGED TEST OBJECTS

F. Brandstätter[1], A. Migliori[2], S. Visser[3], G. Giester[4], D. Topa[1], S. Kuhnt-Saptodewo[5], and C. Koeberl[1,6], [1]Natural History Museum, Burgring 7, 1010 Wien, Austria, franz.brandstaetter@nhm-wien.ac.at, [2]Department of Nuclear Sciences and Applications, International Atomic Energy Agency, Vienna International Centre, PB Box 100, 1400 Wien, [3]Bellevuedreef 40, 2970 Schilde (Antwerp), Belgium, [4]Institute of Mineralogy and Crystallography, University of Vienna, Althanstrasse 14, 1090 Wien, Austria, [5]Weltmuseum Wien, Neue Burg, Heldenplatz, [6]Department of Lithospheric Research, University of Vienna, Althanstrasse 14, 1090 Wien, Austria.

Introduction: The “Weltmuseum Wien” owns a large collection of kris daggers. These objects are famous for their metal blades consisting of numerous layers made by a complicated forging process involving repeated folding and welding of the individual layers. Of special interest are kris daggers from central Java, as it is known that some blades were made by adding meteoritic nickel-iron to terrestrial iron during forging. Most meteoritic metal was taken from the Prambanan iron meteorite, which fell in central Java and is known since 1784 ([1], [2]). The present study is part of a larger project with the aim to identify daggers in the collection of the Weltmuseum Wien that contain nickel-iron metal from the Prambanan meteorite. Due to several restrictions the identification of a meteoritic admixture in the kris blades is not a trivial task [3]. The main complications comprise the exclusive use of a non-destructive method, the size of the objects being ~30 cm in length, the location of suitable areas/spots for chemical analysis, and the limitations inherent to the applied method.

Samples and methods: This study was performed using handheld XRF spectrometry, as this technique has already proven useful for the basic classification of meteorites (e.g., [4], [5]). In a first step, blades of ~200 krisses were checked for areas having significant Ni-contents (in the wt%-range) by using a Bruker Tracer IV-SD XRF analyzer. After this preselection, 7 krisses (inventory numbers 8.044, 23.606, 23.646, 46.049, 119.014, 125.117, 900.382) with the apparently highest Ni-contents (up to 12.5 wt%) were selected for more detailed investigations. In addition, several analogue samples consisting of puddle iron with admixtures of metal from the meteorites Campo del Cielo (sample I) and Gibeon (samples II, III) were investigated. These samples were obtained by a forging procedure similar to the one applied in the production of “real” krisses. Measurements of krisses and analogue samples (spot size ~3 mm in diameter) were performed using a Thermo Scientific Niton Xlt XRF analyser (Ag anode operated at maximum values of 50 kV and a current not producing more than 2 W). Samples I, II, and III were also investigated by a Jeol JSM-6610LV analytical scanning electron microscope (ASEM) and a Jeol JXA-8530F electron microprobe (EMP) at the Natural History Museum, Vienna.

Results and interpretation: The apparent concentrations for Fe, Ni, and Co were calculated using a manufacturer-provided calibration for metals. For a Prambanan test sample the calculated values for Ni (9.6 wt%) and Co (0.83 wt%) are in good agreement with the bulk data of [6]. Altogether 39 spots on both sides of the kris blades were analyzed, yielding significant Ni concentrations, from ~ 0.4 to 12.5 wt%, whereas Co values range from < 0.1 to 1.5 wt%. In test samples I, II, and III the Ni concentrations range from < 0.1 to 2.5 wt%, 0.3 to 1.0 wt%, and 1.4 to 5.8 wt%, respectively. The corresponding Co values range from 0.1 to 0.3 wt%, < 0.1 to 0.2 wt%, and 0.2 to 0.4 wt%, respectively. A detailed ASEM and EMP investigation of the individual Ni-bearing layers in the analogue samples revealed that meteoritic nickel-iron was redistributed during the forging process. Typically, the thin layers (average thickness in the sub-mm range) are chemically zoned, with highly variable Ni concentrations. Measured maximum contents of Ni are 40.4 wt%, 8.0 wt%, and 23.8 wt% in samples I, II, and III, respectively. However, this marked variation of the Ni-content within the layers of the analogue samples is not reflected in the corresponding XRF measurements, indicating that the analyzed area (XRF spot size) is sufficiently large to obtain – at least to some extent - representative averaged compositions. As an overall feature, the measured krisses and analogue samples exhibit a positive correlation between Ni and Co abundances within the concentration range expected for an admixture of nickel-iron from the specific iron meteorites to terrestrial iron. Variations in the concentrations of Ni and Co can be explained by the relative abundance of Ni-rich layers in the analysed spot and/or surface heterogeneities (e.g., by etching). Thus, these preliminary results support the assumption that the selected krisses possibly were made by an admixture of metal from the Prambanan meteorite.

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