IDENTIFICATION OF IRON METEORITES AS PROJECTILES FROM LARGE IMPACT CRATERS.
Gerhard Schmidt, Bensheim (SchmdtGerhard@aol.com).

Introduction: Compositional differences in the platinum group element (PGE) chemistry of chondrites and iron meteorites allow identification of projectile types based on PGE traces in impact melt samples or fallback sediments from large impact craters.

Cretaceous-Paleogene sediments: The impact structure(s) whose impactor led to the PGE abundance patterns in European Cretaceous-Paleogene sediments, or to the global enrichment of Ir (and PGE) at the Cretaceous-Paleogene boundary, has yet to be discovered. An extraterrestrial impact component has been evidenced by the presence of PGE, a fossil meteorite and a carbonaceous chondrite-like (CM2) Cr isotope anomaly (ε^{54}Cr) at the Cretaceous-Paleogene boundary sediments by [1-4].

Chicxulub bolide: The non-chondritic PGE ratios in sediments from the Chicxulub crater are evidence that the globally distributed iridium (and PGE) layer is not preserved in the Chicxulub impact structure, as suggested by [5]. The Chicxulub bolide almost surely cannot be the origin of the global deposition of near-chondritic PGE [e.g., 6] at the Cretaceous-Paleogene boundary. The Chicxulub impact structure on the Yucatán Peninsula in the Gulf of Mexico is most likely formed by an iron asteroid. Based on PGE concentrations in sediment samples from the Chicxulub crater would imply a meteoritic contribution equivalent to ~0.1% Mundrabilla-like iron (Figs. 1,2).

IVB iron meteorites: Near-chondritic PGE pattern are also known from IVB iron meteorites. The Pt/Ir and Ru/Ir ratios from Ternera [7] are similar to those of CI chondrites (Fig. 1). Compared with other iron meteorite groups, the IVB group is compositionally unusual with high concentrations of Ni (~16–18 wt %) and refractory elements, such as Ir [8].

Clearwater East crater: Impact melts from Clearwater East crater (diameter of ~22 km) have the highest fraction of an extraterrestrial component of any terrestrial impact structure. From previous investigations (see [9,10 and references therein]) it is concluded that the crater was probably formed by a chondrite or a member of a still unknown chondrite group.

However, iron meteoritc normalized PGE, Ni and Au pattern of Clearwater East impact melt samples would imply a meteoritic contribution equivalent to ~0.6 to 1.2% IVA Gibeon-like iron (Figs. 3,4) [11].

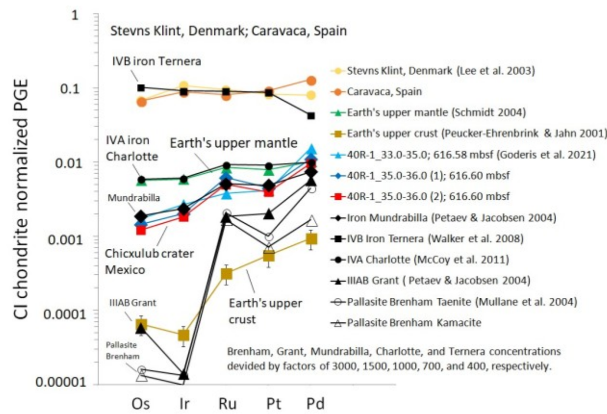

Figure 1. CI chondrite normalized element pattern from Cretaceous-Paleogene boundary sediments [3], Chicxulub crater sediments [5], iron meteorites [7,12, 13,14], Earth's upper crust [15,16], and upper mantle [17]. The Pt/Ir and Ru/Ir ratios of IVB iron Ternera [7] are similar to those of CI chondrites and plot more or less on a horizontal line. IVA iron Charlotte and upper mantle rocks have similar PGE pattern. CI data for normalization were reviewed by [18]. Brenham, Grant, Mundrabilla, Charlotte, and Ternera concentrations were devided by factors of 3000, 1500, 1000, 700, and 400, respectively.

Diagnostic Ir/Rh and Ru/Ir element ratios: The Ir/Rh element ratio permit the best discrimination between the different chondrite groups due to the large difference in the condensation temperature of about 200 K [19]. The Ru/Rh versus Ir/Rh diagram in figure 3 illustrates that a combination of these elements does permit a discrimination between the different chondrite groups and allows the identification of projectiles from impact craters except carbonaceous chondrites and the IVA iron meteorites La Grange, Yanhuitlan and Maria Elena (1935), since these cannot be distinguished by Ir/Rh, Ru/Rh and Ru/Ir element ratios (see data in [13]).

Conclusion: Ir/Rh and Ru/Rh ratios in melt and sediment samples from impact craters allows the differ-entiation of projectile types, except carbonaceous chondrites and some IVA iron meteorites which have similar Ir/Rh, Ru/Rh, and Ru/Ir mass ratios (Fig. 3). Similar to the diagnostic Ru/Ir and Ir/Rh ratios, nucleosynthetic isotope anomalies could still be used

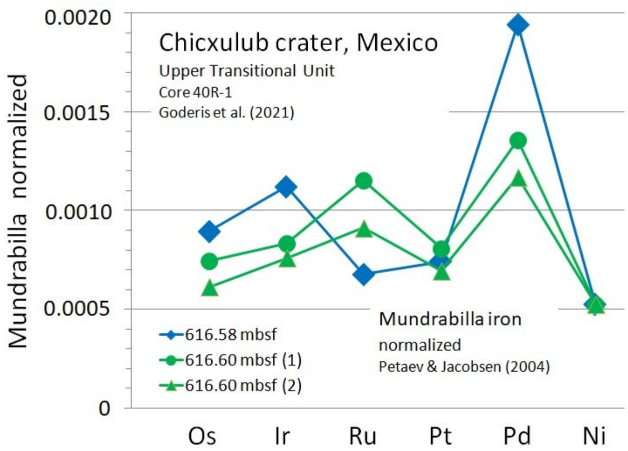

Figure 2. Iron Mundrabilla [12] normalized element pattern from Chicxulub crater sediments [5]. Sediment samples from the Chicxulub crater would imply a meteoritic contribution equivalent to ~0.1% Mundrabilla-like iron.

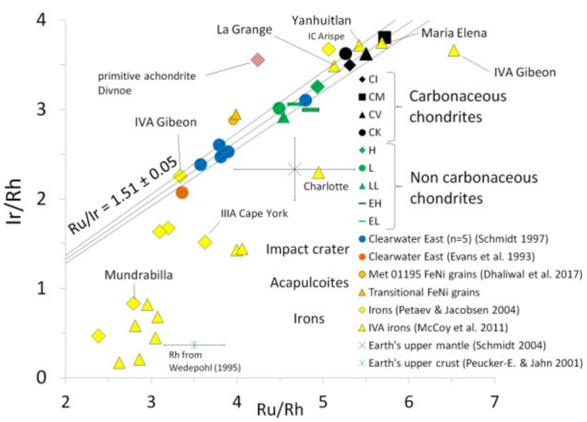

Figure 3. Ruthenium/Rh vs Ir/Rh from carbonaceous chondrites (black symbols), non carbonaceous chondrites (green), iron meteorites (yellow), primitive achondrite Divnoe [12, 13], Earth's upper mantle [17], continental crust [16,20], and Clearwater East melt samples (blue and orange dots) [21,22]. The reason for the different mass ratios of Ru/Rh and Ir/Rh for the IVA iron Gibeon is unclear.

for more precise identification of projectile types of large impact craters [e.g., 23, 24]. About 11 irons were identified from Ir/Rh and Ru/Rh ratios in melt and sediment samples as projectiles of large impact craters with diameters ranging from 4 to 200 km. Except the Morokweng impact structure, South Africa [25,26] all of these large craters were formed by iron projectiles.

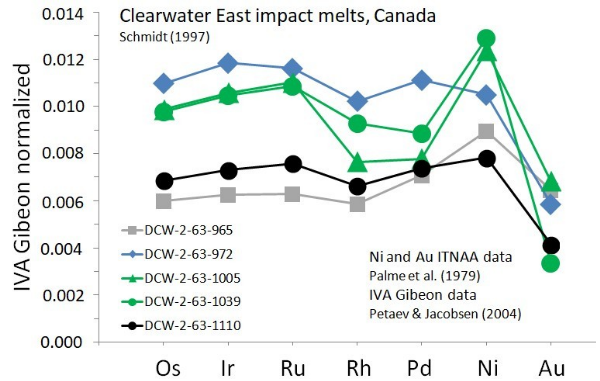

Figure 4. Iron IVA Gibeon [12] normalized element pattern from Clearwater East melt samples. PGE data from [21], Ni and Au data from [27]. Clearwater East impact melt samples would imply a meteoritic contribution equivalent to ~0.6 to 1.2% IVA Gibeon-like iron.

References: [1] Alvarez L. et al. (1980) *Science 208*, 1095–1108. [2] Kyte F. (1998) *Nature 396*, 237 - 239. [3] Lee C.-T. A. et al. (2003) *Geochim. Cosmochim. Acta 67*, 655 - 670. [4] Trinquier A. et al. (2006) *Earth Planet. Sci. Lett., 241*, 780 - 788. [5] Goderis S. et al. (2021) *Science Advances 7*, eabe3647. [6] Goderis S. et al. (2013) *Geochim. Cosmochim. Acta 120*, 417 - 446. [7] Walker R. J. et al. (2008) *Geochim. Cosmochim. Acta 72*, 2198 - 2216. [8] Wasson J. T. and Richardson J. W. (2001) *Geochim. Cosmochim. Acta 65*, 951-970. [9] Palme H. (2008) *Elements 4,* 233-238. [10] Palme H. (2018) *Geochemical Perspectives 7,* pp 116 [11] Schmidt G. (2019) *Large Meteorite Impacts and Planetary Evolution VI,* #5006. [12] Petaev M. I. and Jacobsen S. B. (2004) *Meteoritics & Planet. Sci., 39*, 1685-1697. [13] McCoy T. J. et al. (2011) *Geochim. Cosmochim. Acta 75*, 6821 - 6843. [14] Mullane E. et al. (2004) *Chemical Geology 208*, 5 - 28. [15] Schmidt G. et al. (2005) *Meteoritics and Planetary Science 40*, Supplement, A135. [16] Peucker-Ehrenbrink B. and Jahn B.-m. (2001) *Geochemistry Geophysics Geosystems 2*, 2001GC000172. [17] Schmidt G. (2004) *Meteoritics & Planet. Sci., 39*, 1995 - 2007. [18] Lodders K. (2020) *Oxford University Press.*[19] Wasson J. T. (1985). *New York: Freeman.* p. 267. [20] Wedepohl K. H. (1995) *Geochim. Cosmochim. Acta, 59,* 1217- 1232. [21] Schmidt G. (1997) *Meteoritics & Planet. Sci., 32*, 761-767. [22] Evans N. J. et al. (1993) *Geochim. Cosmochim. Acta 57*, 3737-3748. [23] Warren P. H. (2011) *Earth and Planetary Science Letters 331,* 93 - 100. [24] Kleine T. et al. (2020) *Space Sci. Rev. 216*, 55. [25] McDonald I. et al. (2001) *Geochim. Cosmochim. Acta 65*, 299-309 [26] Maier W. D. et al. (2006) *Nature 441,* 203-206. [27] Palme H. et al. (1979) *Proc. 10th Lunar Planet. Sci. Conf.,* 2465-2492.