The Jbilet Winselwan CM chondrite: an analogue for C-type asteroid sample return

Ashley J. King[1], Paul F. Schofield[1] and Sara S. Russell[1]
[1]*Department of Earth Science, Natural History Museum, London, SW7 5BD, UK*
E-mail: a.king@nhm.ac.uk

In June 2018 JAXA's Hayabusa-2 mission reached its target, the C-type asteroid Ryugu, and in December 2018 NASA's OSIRIS-REx spacecraft will arrive at the B-type asteroid Bennu. The C-complex class of asteroids have been linked to the carbonaceous meteorites, in particular the aqueously altered CI and CM chondrites, and are therefore expected to be chemically pristine and contain volatile and organic species [1]. A major aim for both missions is to collect and return to Earth samples from the asteroid surfaces in order to learn about the formation and evolution of the Solar System.

The Jbilet Winselwan meteorite was found on the 24th May 2013 near Smara in Western Sahara, and with a total recovered mass of ~6 kg is currently the fourth largest CM chondrite (the largest find) [2]. Its bulk C, N and O isotopic compositions and major element abundances are within the range of other CM chondrites [2, 3]. Petrographic observations show that it consists of chondrules and calcium-aluminium-rich inclusions (CAIs, <1 vol%) surrounded by dusty rims and set within a matrix of phyllosilicates, oxides and sulphides [2–5]. Like many CM chondrites, Jbilet Winselwan is a breccia with distinct lithologies that underwent varying degrees of aqueous alteration [2–5]. In most lithologies the chondrules and CAIs are partially altered and the abundance of metal is low (<1 vol%), consistent with petrologic sub-types 2.7 – 2.4, whereas in others the chondrules and CAIs are completely altered suggesting more extensive hydration to petrologic sub-types ≤ 2.3 [2–5]. The brecciated nature of Jbilet Winselwan is also highlighted by variations in H_2O and carbonate abundances when analysing different aliquots of the meteorite [3].

Following aqueous alteration some lithologies in Jbilet Winselwan suffered a period(s) of thermal metamorphism. The matrix often has a "spongy" appearance and melted Fe-sulphide masses are present [4]. Bulk X-ray diffraction (XRD) indicates that the phyllosilicates are dehydrated to a highly disordered phase (~70 vol%) and the abundance of tochilinite, which breaks down at temperatures of ~120°C, is low relative to other CM chondrites [3]. Depletions of volatiles such as He and Cd in Jbilet Winselwan are consistent with a peak metamorphic temperature of 400 – 500°C [3]. However, Göpel et al. [6] found no depletions in volatile trace elements and not all of the phyllosilicates are dehydrated [2], suggesting that the heating was heterogeneous and did not affect all regions within Jbilet Winselwan equally.

The Jbilet Winselwan CM chondrite records a complex history of aqueous and thermal processing on a C-type asteroid. It is one of >20 CM chondrites identified as having experienced both hydration and thermal metamorphism [7]. Aqueous alteration took place when accreted ices melted on the parent body and reacted with the original anhydrous mineral assemblage. The presence of a dehydrated phyllosilicate phase in Jbilet Winselwan implies that thermal metamorphism occurred either simultaneously with, or more likely after, aqueous alteration had ceased. Mineral textures and organic structures in heated CM chondrites indicate that the metamorphism was short-lived, perhaps on the order of hours to several years, consistent with either impacts and/or solar radiation on asteroid surfaces [8]. We favour impacts because depending on the size, velocity and composition of the impactor and target rocks it could produce regions on the parent body with different thermal histories [9], as appears to be the case for Jbilet Winselwan.

Many of Jbilet Winselwan's key properties are similar to Y-793321, which is a sample of dehydrated regolith from the surface of a water-rich asteroid [10]. The visible and near-infrared (IR) reflectance spectra of Jbilet Winsewan, Y-793321 and other heated CM chondrites share a number of features with some low albedo, C-complex asteroids, including Ryugu [11, 12]. This suggests that the surfaces of C-complex asteroids are likely to host a diverse mixture of hydrated and dehydrated phases, and that heated CM chondrites such as Jbilet Winselwan are excellent analogues for the types of materials that will be encountered by the Hayabusa-2 and OSIRIS-REx sample-return missions.

References

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