REPORT OF EMU ACTIVITIES 2012–2016

The European Mineralogical Union (EMU) Executive Committee met in September 2017 at emc2016 (Rimini, Italy). Here follows a short summary of the major points and conclusions from that EMU meeting.

The main achievements of 2012–2016 were EMU’s publishing activities (the EMU Notes in Mineralogy series), the organization of EMU ‘Schools’, the organization of conferences (the European Mineralogical Conference and the Goldschmidt Conference), and awarding scientists who have shown exceptional contributions to their field either with an EMU Research Excellence Medal, an EMU poster prize, or with an EMU grant.

The EMU Notes in Mineralogy series continues to grow. Previously published volumes have now been digitized and are available through GeoScienceWorld. During 2012–2016, five volumes were issued. Among them, EMU12 Kaman Spectroscopy Applied to Earth Sciences and Cultural Heritage achieved the greatest interest. The next four volumes will be released in accordance with the latest trends in our science. To enhance commissioning, production, and marketing, a new agreement has been signed with the Mineralogical Society of Great Britain and Ireland (MSGBI). The production of the Notes is currently a major expense, but that expense has been counterbalanced by improved sales. Income is steadily growing, reaching a record high in 2016. Collaboration with the Mineralogical Society of America (MSA) on educational and publishing projects resulted in EMU Notes being advertised and sold on MSA’s website.

The EMU has, since the very beginning, supported the European Mineralogical Journal. The EMU participates in that journal’s managing committee meetings, nominates one of the chief editors, and helps to solve problems related to the choice of associate editors and to editorial policy.

After the success of Goldschmidt 2013 (Florence, Italy), where mineralogy played a more important role than usual, the European Association of Geochemistry (EAG) provided various slots for EMU activities at Goldschmidt 2015 (Prague, Czech Republic). The same is planned for Goldschmidt 2017 (Paris, France).

The most important award given each year is the EMU Research Excellence Medal. During 2012–2016, Richard Harrison, Diego Gatta, Razvan Caracas, Encarnación Ruiz-Aguado, István Kovács, and Sylvie Demouchy were honoured with this prestigious distinction. Also important are the conference-related EMU prizes. In 2012–2016, EMU awarded 14 poster prizes and awarded grants to dozens of young scientists.

Another very important area of EMU activity is school organization. One occurred in Vienna (Austria) shortly after emc2015, MKR2016 - Mineral Reaction Kinetics: Microstructures, Textures, Chemical and Isotopic Signatures. The next school will be called Mineral Fibres: Crystal Chemistry, Chemical-Physical Properties, Biological Interaction and Toxicity, and will take place 19–23 June 2017 in Modena (Italy).

The committee also discussed the importance of cooperation with other international organizations. Cooperation enhances development and promotes the mineralogical sciences. It is very important to have a forum for discussion and a fast way to communicate news of mineralogical interest in Europe. It seems to be necessary to build and maintain an EMU talk list that can include scientists, students and mineral collectors. This report shows not only the measures and activities undertaken by the EMU Executive Committee but also shows their positive role. For these activities, the outgoing committee deserves the highest appreciation.
CARBONACEOUS CHONDRITE IMPACT MELTS

Nicole G. Lunning¹,² and Catherine M. Corrigan²

Collisions between planetary bodies (such as asteroids colliding with one another or with planets) have played a role in the geologic evolution of our Solar System since the formation of planetesimals, the earliest kilometer-scale bodies. Shock damage from collisional impacts leaves evidence on surviving planetary materials that range in scale from kilometer-sized craters to nanometer-sized mineral structural defects. Impact shock-induced melting is thought to be a common consequence of collisions throughout the Solar System. While ordinary chondrites, martian, and lunar meteorites all exhibit signs of having been melted by impacts, until very recently, no impact melts of primitive carbonaceous chondrites had been recognized (Lunning et al. 2016a).

CARBONACEOUS CHONDRITES

Carbonaceous chondrites include the most primitive known Solar System materials and hold important clues for understanding the origin of the Solar System. Some of their primitive components formed as small objects (≤ cm-scale) in the protoplanetary disk and experienced minimal modification after the accretion of their parent planetesimals (Fig. 1). The primitive nature of carbonaceous chondrites is part of the motivation for the ongoing Hayabusa 2 (JAXA) and OSIRIS-Rex (NASA) spacecraft missions, which will return samples from carbonaceous chondrite-like asteroids. The samples carried back to Earth by these spacecraft will be the most pristine (i.e. will have experienced the least amount of terrestrial alteration) primitive Solar System materials ever studied by scientists on Earth.

The term "carbonaceous" in their name is a bit of a misnomer. Although a few groups within this meteorite class are somewhat carbon-rich (e.g. CI and CM chondrites contain up to wt% quantities of elemental carbon), carbonaceous chondrites do not consistently contain more carbon than other stony meteorite classes (Krot et al. 2003; Scott and Krot 2003).

MISSING IMPACT MELTS

Scott et al. (1992) called attention to the dearth of impact melted carbonaceous chondrite material. The lack of carbonaceous chondrite impact melts might be explained by the meteorites higher volatile concentrations which may prevent the formation of cohesive melts. Many researchers have been searching for these melt features to little avail.

CARBONACEOUS CHONDRITE IMPACT MELTS – FOUND!

Recently, in three separate meteorites, five objects have been identified that appear to be carbonaceous chondrite impact melts. These objects were found by the systematic petrographic examination of the CV chondrites in the Smithsonian Institution’s (USA) thin section library and through the petrological characterization of howardites found in the Grosvenor Mountains (GRO) field area in Antarctica in 1995 (Lunning et al. 2016a,b).

The objects all contain signs that they had rapidly cooled from melts. For example, they contain >60% olivine microphenocrysts, which are strongly zoned with Mg-rich cores and comparatively Fe-rich rims (Fig.

Figure 1

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Figure 2

Schematic illustrating a generalized scenario for impact melt formation. (A) Impact-induced bulk melting. Only very Mg-rich relict olivine (dark green) is not melted. Immiscible silicate (grey) and FeNiS (yellow) liquids are formed. (B) Olivine rapidly crystallizes from the silicate liquid and FeNiS liquid globules and coalesce into larger globules. (C) Olivine continues to crystallize. The five objects referred in the main text were arrested around this point, thereby quenching the silicate liquid into glass and trapping vesicles (if present). Images of the slight variations on the texture between separate objects are illustrated in Lunning et al. (2016a).
Fe-Mg zoning in minerals, such as olivine, indicates they solidified too quickly for solid-state diffusion to homogenize these elements within individual crystals. Some of the olivine microphenocrysts contain relict cores, which are likely the only portion of these objects that remained solid when the rest of the source material melted. All objects contain accessory FeNiS globules, and within those are cellular or skeletal FeNi-metal consistent with rapidly cooled materials. In four of the five objects, the groundmass is vitric glass, indicating they were rapidly cooled and effectively froze before further crystallization could proceed. Several of the objects contain vesicles, which are notably rare in meteoritic materials. To freeze gas bubbles in place and form vesicles, cooling must have occurred more rapidly than the time required for gas bubbles to migrate out of the molten impact melt. These rapid cooling features contributed to the interpretation that these objects are solidified impact melts.

These five objects all have metal- and sulfide-free bulk elemental lithophile element ratios that are consistent with carbonaceous chondrites. This is evidence these objects are impact melts because most other melting processes (on Earth and on planetesimals) fractionate or change the composition of magmas relative to their source material. Additional contextual evidence for each object (see Lunning et al. 2016a) led to the interpretation that four of these objects are CV chondrite impact melts and one is a CM chondrite impact melt. These objects include three fragmental clasts, a melt pocket that formed in situ (Fig. 1), and a melt droplet incorporated after solidification into a breccia primarily composed of achondritic material (specifically a howardite, which is a meteorite breccia possibly from the asteroid 4 Vesta).

**ORIGIN OF THE CM CHONDRITE MELT DROPLET**

Measurements of all three stable isotopes of oxygen (16O, 17O, 18O) obtained through secondary ion mass spectrometry analyses are a powerful tool for assessing the distinct provenance of planetary materials (e.g. Greenwood et al. 2016). The oxygen three-isotopic signature of olivine in the melt object found in the howardite meteorite provided evidence that the object is a CM chondrite impact melt. The nonrelict olivines in this melt object have oxygen three-isotope signatures that overlap the bulk CM chondrite range and do not overlap the ranges of any other known Solar System materials. The relict olivine core in this object has an oxygen three-isotope signature that falls slightly above the carbonaceous chondrite–anhydrous mineral (CCAM) line (Fig. 3) and coincides with the primitive chondrule mineral (PCM) line (Ushikubo et al. 2012). These results further support that this object did not form by impact melting of its howardite host or another member of the howardite, eucrite, diogenite (HED) meteorite clan (generally thought to originate from the asteroid 4 Vesta). Rather, the melt object is composed of CM chondrite impactor material. A CM chondrite was melted upon impact with the parent HED body, ejected a melt droplet, which was solidified in-flight. It was subsequently incorporated into the HED regolithic sediments, which were later collectively lithified to form its host breccia. This CM chondrite melt droplet bears some textural similarity to impact derived crystal-bearing spherules/droplets identified in lunar and martian regolithic samples (Symes et al. 1998; Ruzicka et al. 2000; Udry et al. 2014).

**RELEVANCE TO CURRENT ASTEROID EXPLORATION**

The newly discovered carbonaceous chondrite impact melts have olivine-dominated mineral assemblages, which are notably different from their unmelted precursors. Thus, impact melt-rich regions on carbonaceous chondrite-like asteroidal surfaces may be identifiable using high-resolution mapping during spacecraft missions. JAXA’s Hayabusa 2 spacecraft and NASA’s OSIRIS-Rex spacecraft are currently heading toward asteroids that are thought to be composed of carbonaceous chondrite material. These recently discovered carbonaceous chondrite impact melts may inform site selection for these spacecraft to collect samples and aid in distinguishing impact-modified material from other regolith components in future samples returned via spacecraft missions to these and other Solar System bodies.

**REFERENCES**


Lunning NG and 5 coauthors (2016a) CV and CM chondrite impact melts. Geochemica et Cosmochimica Acta 189: 338-358


Proficiency testing (PT) is a cornerstone of good analytical practice, providing one of the few means of really testing the quality of a lab’s analytical output. Participation in a routine PT scheme can form part of lab accreditation, and for many industrial applications (e.g. ore grade determinations for the mining industry) it is often expected that mineral assay laboratories track their PT results. As an example, National Instrument 43-101, which is Canada’s “Standards of Disclosure for Mineral Projects”, requires the written disclosure of the methods used to verify quantitative data related to new mineral prospects seeking public funding. Hence, proficiency testing has become a de facto component of ore grade assessment whenever a mining company applies for listing on the Toronto stock exchange. Clearly, proficiency testing is not only of research importance but also plays a central role in the world’s mining industry.

So what exactly is a proficiency test? A laboratory will receive a material for analysis and it will submit its results to the PT organizers, who will, in turn, evaluate the submitted result against some benchmark believed to represent the true concentration of the analyte of interest. The critical point about a proficiency testing scheme is that the participating laboratories are required to perform their analyses using routine procedures – no special sample preparation methods, no special efforts towards improved data quality, no extra steps in the quality assurance process are allowed. Thus, if a laboratory’s results closely match the benchmark values then one can have confidence that the analytical methods being used on a routine basis are trustworthy. However, if the report from the PT organizers shows significant discrepancies from the set benchmark then the given laboratory needs to take steps to investigate a so-called “out of control” situation.

The International Association of Geoanalysts (IAG) has operated a whole-rock PT programme since 1996, the first of which involved 49 laboratories reporting concentration results on 51 elements from the Threlkeld microgranite of Cumbria (UK) (Thompson et al. 1996). This round of PT testing involved the dispatch of packets of milled whole-rock powders (Fig. 1) where the participating labs were given three months to report their results. Over the following 20 years, the number of participating labs has now grown to over 100. Likewise, over the years the analytical methods used for such work. The data are plotted in ascending order in terms of the method used for analysis and it will submit its results to the PT organizers, who will, in turn, evaluate the submitted result against some benchmark believed to represent the true concentration of the analyte of interest.

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The IAG’s GeoPT dataset to those derived for the same materials based on painstaking certification projects: few significant differences were found between six such datasets.

Now I would like to present several interesting data sets that reveal the presence of analytical problems which might, in the future, be seen as factors in the participation in a proficiency testing programme, have gone unnoticed. First, I present an example of what might be called a well-behaved dataset for iron in a sediment powder (Fig. 2), which is the norm for such work. The data are plotted in ascending order in terms of the reported Fe₂O₃ (total) concentration. What one sees from this plot is that the data closely approximate a Gaussian distribution (Fig. 2 inset). However, this dataset also shows a few obvious outliers at both the high and the low ends of the mass fraction spectrum. In this dataset, the robust mean of 6.46 g/100 g and the median value of 6.45 g/100 g are in excellent agreement, indicating that there is no significant skewing. Two things are noteworthy: 1) There were a large number of analytical techniques used to obtain the 79 values contained in this report; 2) There appears to be a slight bias of the ICP results towards higher concentrations compared to the XRF data, albeit with the two lowest reported concentration values being from ICP laboratories. Obviously, those dozen or so laboratories that produced results at the extremes of this data spectrum need to investigate their measurement procedures. Nonetheless, the overall distribution of results for iron in this sediment powder looks satisfactory.

In contrast to the dataset shown in Figure 2, I present a dataset for strontium concentrations in the Separation Lake pegmatite (Ontario, Canada) that were reported during the August 2008 round of GeoPT (Fig. 3). Not only do the data show an obvious non-Gaussian data distribution, but there are two distinct plateaus, with the low abundance plateau value of ~8 mg/kg being exclusively populated by laboratories using ICP technology. Furthermore, nearly all members of this group of laboratories used a mass spectrometer as their signal detection system. The second clustering of data around ~35 mg/kg total Sr is dominated by XRF data, but this group also contains a number of analysts reporting results based on ICP technology, the majority of whom recorded their data using an emission spectrograph. The explanation here is easy to understand, in that a common approach for determining total Sr mass...
fraction using mass spectrometry relies on the determination only of the $^{88}\text{Sr}$ content in conjunction with the supposedly known isotopic composition of natural strontium. The Separation Lake pegmatite has an age of 2.64 Ga (Tindle et al. 1998) and a bulk rock rubidium concentration of $2,501 \pm 22 \text{ mg/kg}$ as defined by the robust mean of the proficiency testing data from 64 laboratories. Considering such a high Rb/Sr ratio, a late Archean age and that the half-life of $^{87}\text{Rb}$ is 48 Ga, one can understand that this material’s strontium budget is dominated by radiogenic $^{87}\text{Sr}$. This enrichment in $^{87}\text{Sr}$ will go undetected if the analytical method assesses only the $^{88}\text{Sr}$ in the sample. This dataset should have been a wake-up call for many ICP–MS analysts who might otherwise have continued to make this oversight were it not for their participation in a proficiency testing programme.

A second interesting example involves the MRH-1 rhyolite reference material. The XRF data for zirconium showed a very well-defined mode of around 160 mg/kg, whereas the ICP zirconium results showed a broad spectrum of results with a range of ~200–500 mg/kg. So, why the difference between the XRF and ICP results and the wide range within the ICP results? A clue towards explaining this riddle is that the ICP results depend on whether a mass spectrometer (MS) or atomic emission spectrophotograph (AES) signal detection system was used. Other abbreviations as for Figure 2.

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I hope these few case studies help illustrate some intriguing pitfalls in the analysis of bulk rock samples. Certainly, I think these examples put a spotlight on the power of a proficiency testing programme for revealing shortcomings in a laboratory’s methods. I would like to end by thanking Peter Webb (Milton Keynes, UK), who has been a long-term member of the GeoPT steering committee, Thomas Meisel (Leoben, Austria), who is President of the International Association of Geoanalysts, and Marcus Burnham (Sudbury, Canada) of the Ontario Geological Survey, all of whom provided invaluable assistance in preparing this toolkit contribution. For those geochemists eager to learn more about assuring the quality of their data, I would recommend visiting the proficiency testing section of the www.geoanalyst.org web page.

Best Regards from Potsdam
Michael Wiedenbeck

REFERENCES
Potts PJ, Thompson M, Webb PC (2015) The reliability of assigned values from the GeoPT proficiency testing programme from an evaluation of data for six test materials that have been characterised as certified reference materials. Geostandards and Geoanalytical Research 39: 407-417
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