Magnetic Separation of Gemstones

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INTRODUCTION

Some gems are more magnetic than others, making magnetic separation of gem materials possible. Historically, this approach was hindered by the lack of strength of then available magnets, such as aluminum nickel cobalt ("Alnico"). The powerful neodymium iron boron magnets (NdFeB) available today are many times stronger and currently allow a closer examination of gem materials and their magnetic characteristics.

This work demonstrates a method for the preliminary identification screening of gemstones using test magnets in different configurations.

MATERIALS AND METHODS

Through experimentation, a 0.6 x 2.5 cm rod-shaped magnet and a pair of 0.25 x 0.6 cm disk magnets were selected for this study. These shapes and diameters offered a very strong magnetic field in a manageable, cost-effective size. It was more important to 'quarantine' the test set up from magnetic materials and electrical conductors or air currents in the environment than to use larger magnets, particularly for certain test arrangements. Three approaches were used for testing.

Direct method

In this method the magnet pulled responsive, loose, faceted and cabochon gems across a low friction surface (Figs. 1, 2).

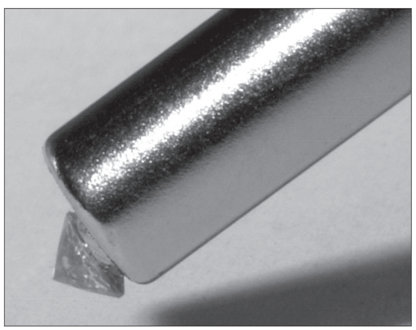

Fig. 1. Demantoid garnet exhibited strong response by the direct method.

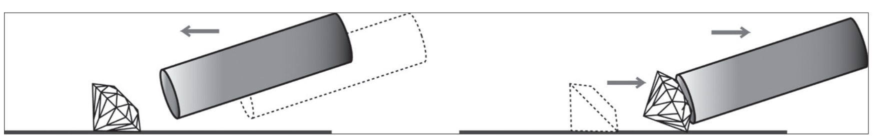

Fig. 2. Efforts to pick up the stone vertically were avoided. Pole face of magnet made contact with largest available face of gem. Magnet was then pulled back horizontally in an attempt to drag gem along a low friction surface. Magnet was kept close to working surface.

Pendulum method

A pair of magnets was snapped over a suspended thread to create a pendulum. Gem specimens were hand held (Figs. 3, 4) or suspended in a gem bag (Fig. 5). Metal tweezers were avoided. In a variation, the gem bag acted as a pendulum, and the hand-held rod magnet pulled the gem suspended in bag. This method was good for testing rough material, gems in nonmagnetic settings, and large faceted specimens.

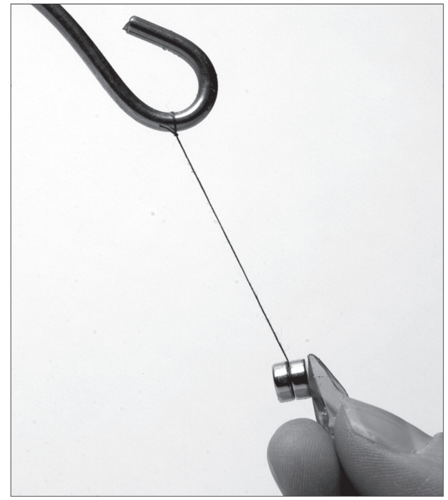

Fig. 3. Gem quality rhodochrosite crystal

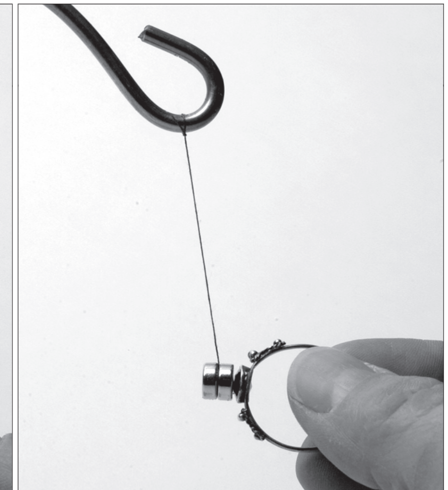

Fig. 4. Almandine set in silver. Silver's diamagnetic behaviour is swamped by the garnet's response.

Floating method

In this approach the gem under test was floated on the surface of a liquid (water) while the magnet was brought slowly into proximity (Fig. 6). Alternatively, the magnet could be floated while the unknown gemstone was moved toward it (Fig. 7).

OBSERVATIONS and DISCUSSION

Test items were either attracted to or repelled by the magnet, or showed no response. Responses for the gems tested by the direct method only are summarized in Table 1. Stones listed in the table as 'responsive' were consistent in their behaviour, and were rarely observed to be non-responsive. This point is essential to an effective elimination process. Types of gems that were normally nonresponsive sometimes displayed a response because of reasons discussed at the end of this section. Gems containing Fe and/or Mn in their chemical formulas tended to respond to varying degrees, with Mn-rich specimens exhibiting a stronger response. These can be

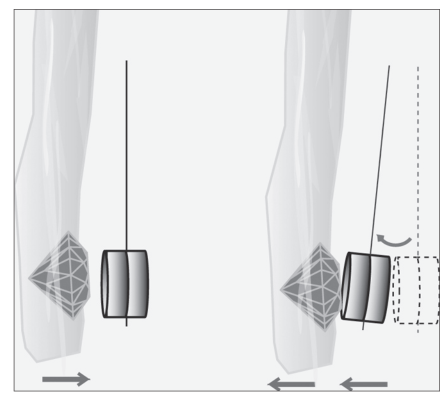

Fig. 5. Pendulum with gem in baggie. Magnet was moved into contact with largest, flattest surface of gem, then pulled back.

Table 1. Magnetic separation of loose stones by the direct method

Stone colour Mostly transparent	**Responsive** Highlighted gems exhibited a relatively strong response.	**Nonresponsive** (Magnetic inclusions can occasionally give a misleading result.)	**Both responsive and non responsive**
Red and pink	Almandine, rhodolite, red **GGG, rhodochrosite, rhodonite,** pink cubic zirconia (and many other Mn-rich collector's stones	Ruby, pink sapphire, red and pink spinel, pink topaz, pyrope (approaching end member), zircon, glass, plastic, red cubic zirconia	Tourmaline, pyrope (departing from end member), garnet-topped glass doublet
Blue and purple	**Blue GGG, "**True Blue" beryl (weak)	Aquamarine, natural and synthetic sapphire, synthetic blue spinel (various shades), scapolite, glass, plastic, amethyst, topaz	Natural blue and violet spinel, tourmaline, garnet-topped glass doublet
Green	**Demantoid, green GGG**, peridot (sometimes weak)	Sphene, zircon, cubic zirconia, tsavorite (approaching end-member grossular), sinhalite, sapphire, apatite, emerald, green beryl, soudé spinel triplet, jade, glass, plastic	Green grossular (departing from end-member grossular), tourmaline, garnet-topped glass doublet
Yellow, orange and brown	**Spessartine, yellow andradite**	Hessonite (near end-member grossular), yellow sphene, citrine quartz, topaz, sapphire, scapolite, zircon, orange cubic zirconia, fire opal, orange and yellow glass, plastic	Hessonite departing from end-member grossular), tourmaline, garnet-topped glass doublet
Colourless	**Colourless GGG**	Cubic zirconia, zircon, synthetic moissanite, sapphire, glass, plastic, YAG, strontium titanate, topaz	Garnet-topped glass doublet
Black (mostly opaque specimens)	**Star diopside (magnetite needle-like inclusions), melanite, yttrium iron garnet,** black cubic zirconia	Onyx, obsidian, glass, plastic, epidote, jet	Black star sapphire (depending on the presence of magnetite vs. rutile inclusions), hematite (rough, unprocessed hematite often nonreponsive)
Colour Change (and highly pleochroic specimens)	Colour-change garnet	Alexandrite, colour-change corundum, andalusite	Tourmaline

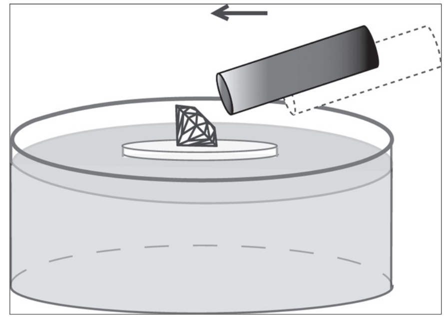

Fig. 6. Gem placed on buoyant material with largest flat face exposed for best interaction. Magnet is slowly moved toward gem and behaviour is observed. Good for observing subtle responses.

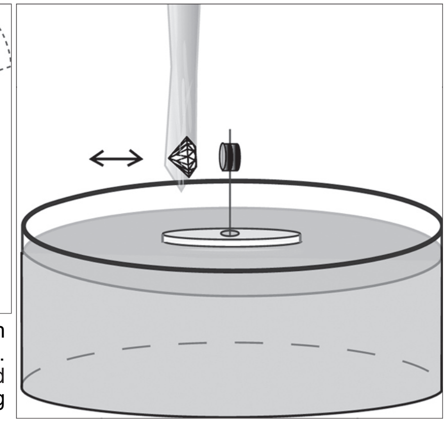

Fig. 7. Pair of disk magnets snapped over vertical piece of buoyant material. Pole axis was horizontal. Needs care to quarantine the working space from local competing fields.

separated out quickly and easily. Certain colours of cubic zirconia and all colours of gadolinium gallium garnet (GGG) also responded, the latter relatively strongly. Earlier research supports some of these findings (Biswas, 1974; Haralyi, 1994; Hanneman, 2002). Within the garnet group, the following types could be separated: see again Table 1.

spessartine vs. $Mn^{++}{}_3Al_2(SiO_4)_3$	hessonite (approaching end-member grossular) $Ca_3Al_2(SiO_4)_3$
demantoid vs. $Ca_3Fe^{+++}{}_2(SiO_4)_3$	tsavorite (approaching end-member grossular) $Ca_3Al_2(SiO_4)_3$
almandine vs. $Fe^{++}{}_3Al_2(SiO_4)_3$	pyrope (approaching end-member) $Mg_3Al_2(SiO_4)_3$

Technically, there are several types of magnetism that will cause a material to be attracted to a magnet, but it is beyond the scope of this work to distinguish between them. For this discussion, these magnetic behaviours will be lumped under the term 'ferromagnetism'.

Results indicate that the ferromagnetic behaviour observed in this study results from the presence of ferromagnetic elements present in the chemical formula of the mineral. Iron, manganese and gadolinium are all known as ferromagnetic materials either on their own or in compounds. The fact that pyrite (FeS_2) does not show detectable magnetic response by the 'direct test' method demonstrates the influence of element valence and the microscopic details leading to magnetization.

This work suggests that minerals with no ferromagnetic elements in their formulas are unlikely to exhibit obvious magnetic attraction, even if traces of such elements are present as impurities. An open question at this point is the cause of colour and magnetic response in cubic zirconia.

Magnetic inclusions were occasionally observed to cause a misleading response, and must be taken into account, as must the possibility of isomorphous replacement in some gems (e.g., iron or manganese substituting for calcium, aluminum, or magnesium in tourmaline and garnet).

The floating method was the most sensitive of the test configurations. Its ability to detect very subtle responses made it helpful in identifying garnet-topped doublets, or distinguishing between turquoise and plastic. The variation where the magnet floated while the specimen was hand held was useful for gem-set jewellery or large pieces of rough, but was extremely sensitive to competing fields. For this reason the direct method should always be the first test used. The floating technique could also detect weak diamagnetic responses in which the magnet and specimen repelled one another. Diamagnetism is present in all materials, but is generally orders of magnitude weaker than ferromagnetism, yet it was observed here for silver and some gem materials lacking ferromagnetic elements. Generally a ferromagnetic response from a gemstone will swamp the diamagnetic effect of a silver setting (Fig. 4). Care must always be taken, however, to test gem settings, because ferromagnetic elements are present in many commonly used alloys.

CONCLUSIONS

The response of gemstones in a magnetic field has been shown to provide a useful initial screening technique for identification. Results were not diagnostic, however, and conventional gemmological testing is recommended to support this magnetic separation approach.

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CGA's 17th Annual Gem Conference Toronto, 2006

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The Canadian Gemmological Association's seventeenth annual gem conference and graduation was hosted in Toronto at the prestigious Ontario Club. This year's conference, held on Saturday, October 28, was a one-day event that nevertheless offered enough information and excitement to rival its lengthier predecessors.

This year's keynote speaker, Richard W. Hughes, of the American Gem Trade Association, Gem Testing Center, led the list of presenters with his talk "From Madagascar to Malyshev: In Search of the Precious Stone". For nearly thirty years, Mr. Hughes, a world–renowned expert in corundum, has been an explorer, a seeker not only of ruby and sapphire but also of wisdom and experience. In his fascinating presentation, he took us along with him on his quest for gemstones in some of the most exotic and inaccessible places on the planet. From the emerald and alexandrite mines of the Ural Mountains to the ruby and spinel mines of Tajikistan, Mr. Hughes and his colleagues made their way past KGB checkpoints and through al Qaeda territory in the course of their journeys.

It is, however, the island of Madagascar that holds a special fascination for him and about which he spoke at length. Approximately the size of California, Madagascar lies 400 km off the east coast of Africa. Mr. Hughes explained that it owes its mineralogical richness to its unique geologic pedigree. About 165 million years ago, Madagascar lay at the centre of the supercontinent Gondwanaland with its closest neighbours east Africa, southern India and Sri Lanka. Not surprisingly, much like these three regions, it is blessed with extremely rich gem deposits. In fact, Mr. Hughes considers Madagascar a gemmological "new frontier". There are corundum deposits throughout the country, but at present the two most productive areas are Ilakaka in the south and Andilamena in the north. Ilakaka in particular is Madagascar's Sapphire Central. This region is noted for its huge production of pink sapphires, although some very fine blue sapphires are also mined. Andrebabe also produces fine sapphire.

President Duncan Parker and keynote speaker Richard Hughes. Photo: Q. Wight.

Throughout his presentation, Mr. Hughes encouraged us also to be explorers. He believes strongly in travel. In order to be certain of the origin of a gemstone, he tells us, we must "go to the source". There is, however, an even more important reason to travel. He wants us to see, appreciate, and engage the world around us. The beauty of the people he has encountered has impressed him