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# Some Aspects of Mineralogy and Gemology in Muslim Civilisation


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# SOME ASPECTS OF MINERALOGY AND GEMOLOGY IN MUSLIM CIVILISATION

## Summary

Many Muslim scholars dealt with minerals and gems and wrote monographs on the subject. The golden age of their writings was the 4th-5th century after Hijra (AH) (10th-11th century AD). They used almost all the physical properties known to us now to identify and differentiate minerals. Experimentation was a widespread habit in the study of minerals. Al-Biruni, in the author's view, was the leading scientist in this subject.

## 1- Introduction

Mineralogy is the science studying "minerals". A mineral is a naturally occurring substance that has a definite chemical composition and crystal structure. In other words, a mineral is a crystalline, chemical pure, natural material. Accordingly, gold, diamond, quartz, calcite, sapphire, pearl, ... etc are examples of minerals. The importance of minerals and mineral resources are well known and do not need to be mentioned here.

Gems and precious stones are special types of minerals. They are rare, beautiful (in colour, transparency, lustre, ... etc), and hard enough to resist physical and chemical changes for some time. Diamond, ruby, sapphire, emerald, ... etc have these properties; they are gems and, of course, minerals. The importance of gems to emperors, kings and wealthy women was possibly the driving force behind their recognition since the dawn of human civilization.

Certain varieties of mineral, precious stones, and gems were known to the Ancient Egyptians, Mesopotamian people, Ancient Indians, Greeks, and Romans. Most of the lands of these people became part of the Islamic State "Caliphate". Consequently, their writings on gems and minerals, as was the case with other subjects, were translated into Arabic in the first 3 centuries A.H. Thus, it is not surprising to find the best contributions by Muslim scientists to mineralogy and gemology in the 4th and 5th centuries A.H.

## 2- Scientists of the Subject

Most of what was written in the subject of minerals, stones, and gems was lost. A few monographs survived, and are now printed. In addition, information on the subject can be found in some encyclopedic works. These are some examples:

- Yahya Bin Masawaih (died 242 AH/857 AD), Gems and their properties.
- Al-Kindi, Ya'koub Bin Ishaaq (260AH/873AD) wrote three monographs, the best of which is "Gems and the Likes". It was cited by other writers in the subject. However, it was lost.
- Al-Hamdani, Al-Hasan Bin Ahmad (334AH) wrote three books on Arabia in parts of which he described methods of exploration for gold, silver, and other minerals and gems, their properties and locations.

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- Ikhwaan As-Safa (2nd half of the 4th century AH) wrote an encyclopedic work, which included a part on minerals, especially classification.
- Al-Biruni, Abu Ar-Rayhan Mohammad Bin Ahmad (440AH/1048AD) is in the authors view the leading mineralogist throughout the Islamic history. His monograph "Treatises on how to recognize gems"( Al-Jamhir fi Ma'rifatil Al-Jawahir) is probably the best contribution on mineralogy in the Muslim civilization. Throughout this manuscript, Al-Beruni did not translate or copy the science of other civilizations. Instead, he recorded his own experience.
- Al-Tifashi, Ahmad Bin Yousef (683AH), "Flowering Ideas on Gemstones"(Azhar Al-Afkar fi Jawahir Al-Ahjar) Although it is more than 200 years after the work of Al-Bierouni, it is of lower scientific value. However, it is much superior both in classifying minerals and in the method of studying them, which is very close to what we see now in modern mineralogy books.
- Ibn Al-Akfani, Mohammad Bin Ibrahim (749AH/1348AD), "Special Treasures on Characteristics of Gemstones" (Nukhab Al-Thakhair fi Ahwaal Al-Jawahir). This monograph is scientifically of lesser quality than that of Al-Tifashi.

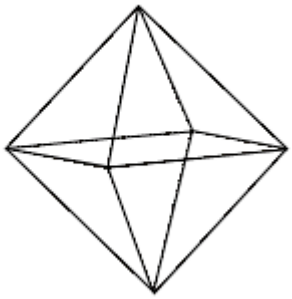

Fig. 1 (left) Diamond crystal as described by Al-Biruni and drawn by the author.
Fig. 2 (right) Quartz crystal as described by Al-Biruni and drawn by the author.

## 3- Methods of Study

Since the dawn of human civilization up till the 18th century AD, minerals had been studied by the use of their physical properties; e.g. colour, luster, hardness, crystal habit, ... etc. Whilst Muslim scientists used the same set of physical properties as scholars before and after them, they also made original contributions to the subject. The following are some examples of these properties and how they were used by the Muslim scientists to identify certain minerals.

## 3.1- Colour

Colour is what you see with the naked eye in the specimens. It was used extensively to subdivide a gem into several varieties. Yaghout (ياقوت), now known as corundum, was divided into four types; each was subdivided into several varieties.

- Red = present day ruby. Seven varieties were identified.
- Yellow = Yellow sapphire. Five varieties were identified.
- Blue = sapphire. Five varieties were identified.
- White = white sapphire.

Since colour is misleading in the identification of minerals, it is important to emphasize their ability to put all these coloured varieties in one gem category: Yaghout or corundum. To do this, they depended on other properties beside colour.

## 3.2- Streak

Streak is the colour of the mineral powder when scratched. It is still used now to differentiate, for example, between minerals which have the same colour but vary in their streak colour. This property was used by Al-Biruni to group several varieties of hematite Fe2O3 (Shathenj شاذنج ) under one mineral.

## 3.3- Dispersion

This is the ability of a mineral to analyze the white light into its seven components, violet – red. Diamond is one of the minerals which have this property. To Muslim scholars, the higher the quality of diamond, the better it disperses light.

## 3.4- Hardness

Hardness is the ability of a mineral to scratch other minerals. The scratched mineral is the softer of the two. This property was well known to Muslim scholars, to the degree that they arranged the known minerals according to their hardness. Al-Bierouni wrote in his monograph "Al-Jamaher ..." p. 66": "I have started my book describing diamond before all other gems because it is the leader or master. It scratches Yaghout (corundum) and Yaghout scratches what comes below it. However, Yaghout can not scratch diamond. ... etc" (Author's translation). This is exactly our present knowledge of both minerals. Al-Bierouni also differentiated between diamond and a variety of quartz by hardness. A lot had been written on this property; the above few lines are enough to explain the idea.

## 3.5- Habit

Habit is the most common natural form or shape of the mineral. It is a reflection of its crystal form. This important property was also frequently used by Muslim scholars to differentiate between minerals. Let us translate the habit of diamond from Al-Tiefashi (author's translation): "... and of the properties of diamond, all types have right angles, six or eight or more, the faces are triangles. If it is broken, faces will be triangular even at the smallest parts, ..." . This is true because we now know that diamond is of the cubic crystal system, and its more important habit is the octahedron.

Al-Biruni, p. 94-95 differentiated between diamond and Yaghout, and diamond and quartz using the crystal habit. Figures 1 and 2 are drawn by the author according to the descriptions of Al-Biruni.

## 3.6- Specific Gravity

This is another important property coined by Al-Biruni, where he measured the specific gravity of several minerals for the first time to my knowledge. He invented a simple apparatus to do this (Fig. 3). The procedure may be simple, but the results are accurate and reproducible. The conical apparatus is filled

with water to the mark. Then, a piece of the mineral is weighed and put in the apparatus. The volume of the displaced water is determined, which equals the volume of the piece of the mineral. The specific gravity of the mineral was calculated in reference to a standard volume of the yellow-orange Yaghout (corundum), and NOT TO WATER as we now calculate it. The specific gravity of the standard (Kutb قطب ) yellow-orange Yaghout was 100 Mithkal. In other words, he was comparing the weights of equal volumes of the minerals and the Kutb Yaghout. The experiment was the same as the current practice for measurement, except that we now use water as the reference material with a specific gravity of 1. Table 1 shows the specific gravity of some minerals and materials relative to Kutb Yaghout.

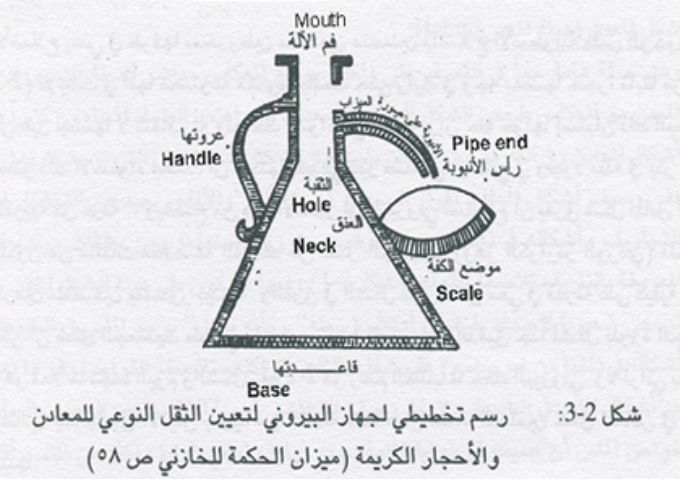


Fig. 3 A sketch of Al-Biruni apparatus which he used to determine the specific gravity of gems and minerals.

**Table 1**

Specific gravity of some minerals and materials relative to the Kutb yaghout (From Al-Khazen, Mizan Al-Hikma, p. 58).

| Name of the gem | **Gem weights of equal volumes to Yaghout** | | | |
|---|---|---|---|---|
| | Their weights when equal to the volume of 100 Mithkal of Yaghout | | | Total Tasaseej |
| | Mithkal | Dawanik | Dawanik | |
| Yaghout | 100 | - | - | 2400 |
| Ruby | 97 | - | 3 | 2331 |
| Spinel | 90 | 2 | 3 | 2171 |
| Beryl | 69 | 3 | - | 1671 |
| Lazaward | 67 | 5 | 2 | 1630 |
| Pearl | 65 | 3 | 2 | 1574 |
| Agate | 64 | 4 | 2 | 1554 |
| Agate | 64 | 4 | 1 | 1549 |
| Onyx & Quartz | 63 | - | 3 | 1525 |
| Pharos's Glass | 62 | 5 | 1 | 1509 |

Dawanik are parts of Mithkal, Tasaseej are parts of Danik.

The above numbers are of less use until they are converted to specific gravity on the basis of water = 1 i.e. to numbers that can be compared to what we have in modern mineralogy books. To do this, find out the modern specific gravity of Yaghout or corundum (it ranges from 4.01 to 4.4). This is equal to 100 Mithkal or 2400 Tasaseej. Then convert all other numbers to get the modern specific gravity for the above gems as shown in Table 2. Note that the modern specific gravity for the above gems is a range rather than a single value, because of impurities inherited in their genesis. Also, the exact composition of the reference variety of Yaghout used by Al-Biruni is not known. Consequently, some differences are present. However, they are small enough to indicate the accuracy of Al-Biruni's experiments.

**Table 2**

Some of the specific gravities of Al-Bierouni compared to modern values.

| Name | **Al-Biruni's values** | | |
|---|---|---|---|
| | Their weights when equal to the volume of 100 Mithkal of Yaghout | | Modern Values Water = 1 |
| | Yaghout = 100 | Water = 1 | |
| Ruby | 97.125 | 4.01 | 4.4 |
| Spinel | 90.458 | 3.73 | 3.99 |
| Beryl | 69.5 | 2.86 | 2.678 – 2.775 |
| Pearl | 65.58 | 2.7 | 2.65 – 2.684 |
| Agate | 64.75 | 2.67 | 2.5 – 2.7 |
| Coral, polished | 64.54 | 2.66 | 2.6 |
| Syrian Glass | 63.125-62.79 | 2.6 – 2.59 | 2.5 – 2.45 |
| Quartz | 62.6 | 2.58 | 2.58 |
| Sabaj=Jet | 28 | 1.15 | 1 – 2 |
| Amber | 21.40 | 0.88 | < 1 |

## 4- Experimentation

One should not expect Muslim scientists to perform complicated experiments using sophisticated equipment in the manner of present day mineralogy. Experiments were focused on the physical properties of the minerals, in order to differentiate or identify them. Some of the Muslim scientists had slightly experimented on minerals, like Ibn Masawaih; others had frequently used experiments, like Al-Tiefashi; and a third class of scientists acquired all their knowledge of minerals through experimentation, like Al-Biruni. The following example is cited because it is short enough to include in the article.

Al-Biruni wrote in his book "Al-Jamahir ...", p. 58, while talking about Yaghout (ruby): "...I (Al-Biruni) bought some raw pebbles brought from India. I heated some of them, they became more red. There were two very dark pieces, one was with reddish colour, the other was less red. I put both pieces in a crucible and directed the flame at them for a period sufficient to melt 50 Mithkal of gold. I took the pieces after cooled. I noticed that the less red piece became purer with a rose red colour. The other, deep red piece lost its colour and became like Sarandeep (now Sri Lanka) quartz. I then examined this latter piece and

found that it was softer than the Yaghout. …. . I concluded: when redness is lost with heating, the heated material is not Yaghout. This conclusion can not be reversed; i.e. if the heated material stays red it is not necessarily Yaghout, because iron stays red after heating". Author's translation.

There are several tests in the above paragraph:

- Al-Birouni first classified the pebbles as red yaghout (ruby).
- Two pieces were doubtful on the basis of their colour.
- The colour was tested by heating the two pieces.
- They were then tested for their hardness.
- Then a general conclusion was made for the whole work.

There are many other experiments where more than one physical property is used to identify a mineral or a gem.

## 5- An Example of Other Writings

Let us end this article by giving an example of other writings in the field of mineralogy. The example is Sabaj (known now as jet). The writings on diamond or Yaghout is too long to copy.

> "This is not a gem. … . It is a deep black stone, sageel, very soft, light, and burns with fire. It ignites if heated by the sun's rays and has a petroleum smell which is in agreement with our (his) descriptions. It is a solidified petroleum very much like the black stones used to heat ovens in Fardhanah (now in Ozbecstan). This is because the asphalt, bitumen, and petroleum rises in the mountain in Farghanah. ….few lines on the metals and minerals in Farghanah. … . The best Sabaj quality comes from Tous (now in Iran), it is used to make mirrors and utensils, and usually found in black, wetted, rotten land. …. It is also brought from the Dead Sea area. Its specific gravity relative to Yaghout is approximately 28. The type brought from Samarkand has a specific gravity of 26.25 (around 1 relative to water). I (He) did fixed his weight relative to Yaghout because of the abundance of bubbles within it which increase the volume and decrease the weight." P. 68, "Al-Jamahir…". Author's translation

Note the wealth of information in the above paragraph:

- Areas from which it is brought or mined
- Detailed physical properties
- Variation in specific gravity and its causes
- Genesis: its relation to petroleum
- Uses

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