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Identification of Minerals and Ore Minerals by Classical and Conventional Methods: A Review

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ABSTRACT

Rasashastra is a branch of Ayurveda concerned with various minerals, including Maharasa, Uparasa, Sadharanrasa, Ratna (Precious stones), Upratna (Semi Precious stones), Dhatu (Metals), etc. These minerals are essential in the preparation of a variety of medicinal formulations, and the therapeutic effectiveness heavily relies on the authenticity of the raw materials used. In contrast to ancient times when these genuine raw materials were readily available in nature's abundance, today, their scarcity and difficulty in identification have led to the development of artificial alternatives for medicinal purposes. However, the utilization of artificially created minerals can potentially alter or impact the therapeutic value of the medicines derived from them. Therefore, the accurate identification of minerals and ores has become a crucial task. Ayurvedic classical literature provides guidelines known as "grahya lakshanas" or acceptable characteristics for identifying genuine mineral samples. Some of these grahya lakshanas resemble the physical properties of minerals discussed and utilized in the field of mineralogy. Consequently, there is a contemporary need to incorporate the parameters employed by geologists for mineral and ore identification alongside Ayurveda's classical grahya lakshanas as an interdisciplinary approach. In the present study, a collaborative effort has been established with the Geology Department of GSS College, Belgaum, as part of a memorandum of understanding (MoU) continuation initiative.

Keywords: Mineral, Ore Mineral, Grahya Lakshana, Physical Properties and Rasashastra.

INTRODUCTION:

The Rasashastra branch of Ayurvedic science extensively documents the study of Rasadravyas or alchemy. Ancient acharyas described the best varieties of minerals and ores for therapeutic purposes based on specific physical attributes, known as grahya lakshanas (acceptable attributes). However, in today's rapidly evolving era characterized by technological advancements, minerals used for therapeutic purposes are often artificially manufactured rather than sourced from natural origins. This alteration in traditional preparations has made it challenging to rely solely on traditional criteria to determine the authenticity of a drug. To address this issue, it becomes imperative to consider geological factors when establishing the standard grade of minerals. When geological criteria are combined with grahya lakshanas, they play a significant role in determining a drug's originality in its raw form. This integrated approach ensures the selection of the perfect raw material, leading to the production of high-quality medications. Geology, as a comprehensive scientific field, encompasses the study of rocks and minerals among various other branches. Geological principles for identifying minerals and ores involve assessing physical parameters such as color, streak, lustre, fracture, cleavage, etc. Nevertheless, for more precise identification and confirmation of minerals, advanced techniques like studying the minerals under petrographic microscope, chemical analyses and instruments such as the Atomic Absorption Spectrometer (AAS), X-ray fluorescence (XRF), and X-ray diffraction (XRD) can be employed.

Materials and methods:

In the present study, the Physical properties of minerals and ore minerals are being discussed. Reviewing the classical textbooks of Rasashashtra for the mentioned grahya lakshanas of minerals, an effort is being made to compare them with the physical and chemical properties of minerals and ores that are available in the mineralogical literature. In this review, only a few selected minerals and ores that are commonly used for the preparation of medications are presented. For a better understanding table 1 is presented to exhibit the classification of economic minerals, many of which are commonly used in Rasashastra. Table 2 is presented to exhibit the minerals that are used in Rasashashtra with their grahya lakshanas whereas Table 3 presents the physical parameters for the identification of the same minerals used in Geology (where NA is Not Applicable).

Table 1. Classification of Economic Minerals[1]

Mineral Fuel	**Non-Fuel**								
	METAL				**INDUSTRIAL**				
	ORE			**PRECIOUS**	**NATURAL AGGREGATES**		**GEMSTONES**	**MEDICINAL**	**CONSTRUCTION**
	Ferrous	**Non-Ferrous**	**Ferro -Alloy**		**Ubiquitous**	**Local**			
-Coal -Petroleum -Natural Gas	-Iron-Ore	-Phosphate -Copper -Zinc -Aluminium -Tin	-Manganese -Cobalt, Nickle	- Gold -Silver	-Sand -Cement	-Salt -Phosphate	-Diamonds -Emeralds -Rubies	-Mica -Chalcopyrite -Pyrite -Sulfur -Haematite -Cinnabar	-Gypsum -Kooline -Limestone -Sandstone -Marble -Haematite

Table 2. Minerals that are used in Rasashashtra with their grahya lakshanas.

S. No.	**Minerals & Ores**	**Grahya Lakshanas**	**References**
1)	Swarnamakshika (Gold)[2 & 3]	Snigdha, guru, shyamal kanti, kashe swarna dyuti,suprakasham,konojhitam, swarnasamanvarna	R.T. 21/4
		Swarnavarna, guru, snighdha, ishad neelchavi sphutam, kashe kanakvad ghrishtam, kalima vikiretu ghristam	A.P. 4/8
2)	Abhraka (Biotite)[4 & 5]	Snigdha,prithudal, varnyasanyuktam, sukhanirmochyapatram	R.R.S. 2/11
		Neelanjana upmam, snigdha, bharpurna, maha-ujjawalam, nirmochyapatram, mridula	R.T. 10/13
3)	Sasyaka (Azurite)[6]	Shikha kantha samachchayo, guru, snigdha, maha-ujjawalam	R.T. 21/72
4)	Gandhaka (Sulphur)[7]	Sukapicha samachchayo, navneetsamprabha, masruna, kathin, snighdha	A.P. 2/20
5)	Patra-Haratala (Orpiment)[8]	Swarna varna, guru, snigdha, tanupatra	R.R.S. 3/66
6)	Hingula (Cinnabar)[9]	Japakusum varnabha, peshane sumanohara, mahaujjawalo, bharapurna	R.T. 9/3
7)	Swarna (Gold)[10]	Komala, raktapitabh, snigdha, shulvenduvarjitam, guru	R.T. 15/12
8)	Manikya (Ruby)[11&12]	Kusheshyadala chayam, swacham, snigdham, guru, vrita ayatam, samam gatram	R.R.S. 4/9
		Rakta utapala dala, ramyam, deeptaprabha, vritayatam, samangam	R.T. 23/44
9)	Praval (Coral)[13]	Pakva bimbi phala chayam, vritayatam, avakrakam, snigdham, avranakam, sthoolam	R.R.S. 4/17
10)	Vajra (Diamond)[14]	Snigdham, vyudhita vibham, swachyam, alekhyam cha vilekhanam, teekshanam, shadha konam, ashta astram	R.T. 23/6
11)	Sphathikamani (Rock crystal/Quartz)[15]	Sheetam, snigdham, nistusham, netrahridyam, ghrishtam dhate swachatam purvatulyam, swacha chayam	R.T. 23/213
12)	Godanti (Gypsum)[16]	Patrachitam, masruna, sharad indu sunirmalam, deepta prabham	R.T.11/239

Table 3. Physical parameters for mineral identification

INERALS & ORES	PROPERTIES								
	Chemical composition	**Colour**	**Specific gravity**	**Lustre**	**Streak**	**Cleavage**	**Hardness**	**Diaphaneity**	**Crystal System**
Chalcopyrite[17]	$CuFeS_2$	Brass yellow	4.1-4.3	Metallic	Greenish black	Poor or indistinct	3.5-4.0	Opaque	Tetragonal
Biotite[18]	$K_2(Mg\ Fe)_2$	Brown or black	2.7- 3.3	Pearly	Greenish black	Perfect	2.5-3.0	Transparent	Monoclinic
Bornite [19]	Cu_5FeS_4	Blue, purple, and hues such as peacock green and gold.	5.0-5.1	Metallic	Dark grey to black	Poor or absent	3	Opaque	Orthorhombic
Sulphur[20]	S	Yellow, brownish or greenish yellow, orange, white	2.0- 2.1	Resinous, greasy	Yellow	Imperfect	1.5-2.5	Transparent or translucent	Orthorhombic
Orpiment[21]	As_2S_3	Lemon yellow to golden yellow	3.4-3.5	Pearly,resinous or dull	Yellow	Perfect	1.5-2.0	Subtransparent-subtranslucent	Monoclinic
Cinnabar[22]	HgS	Reddish	8.09	Adamantine	Scarlet red	Perfect	2.0-2.5	Subtransparent to opaque	Trigonal
Gold[23]	Au	Golden yellow. whitens when naturally alloyed with silver	19.3 when pure	Metallic, does not tarnish	Metallic gold yellow	None	2.5 – 3.0	Opaque	Isometric
Ruby [24]	Al_2O_3	Red (pinkish red to deep blood red)	3.97-4.05	Vitreous	Colourless	None	9.0	Transparent to opaque	Trigonal
Coral[25]	$CaCO_3$	White, pink, red, orange, and black	NA	Dull to waxy	NA	NA	3.5	Opaque	NA
Diamond[26]	C	Usually, Colourless	3.52	Adamantine to greasy	Colourless	Perfect	10	Transparent, Translucent, Opaque	Isometric
Quatz (Rock crystal) [27]	$Si0_2$	Common colors are clear, white, gray, purple,	2.6-2.7	glassy	Colorless	None	7	Transparent to Translucent	Hexagonal

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		yellow, brown, black, pink, green, red.							
Gypsum[28]	$CaSO_4.2H_2O$	Colourless or white	2.31	Pearly, sub-vitreous or dull	White	Perfect	1.5-2.0	Transparent-translucent	Monoclinic
Talc [29]	Mg_6 (Si_8O_{20}) $(OH)_4$	White, silvery white and greenish	2.58-2.83	Pearly	White	Perfect	01	Sub-transparent to translucent	Monoclinic

Several Grahya Lakshanas described in Ayurvedic classics can be correlated with the physical properties used in geological science for mineral identification. While not all Grahya Lakshanas have direct parallels in geology, certain attributes align with established geological parameters, providing a common ground between the two disciplines. The table no. 04 below is an attempt to highlight these intersections, illustrating how traditional Ayurvedic attributes and modern geological properties complement each other, thereby offering a more comprehensive framework for mineral identification.

Table 4. Familiarity between grahya lakshanas and physical properties of minerals and ores

S. No.	Minerals & Ores	Grahya Lakshanas	Physical properties
1)	Swarnamakshika (Chalcopyrite)	Suprakasham	Metallic lustre
		Swarnavarna	Brass yellow colour
		Kalima vikiretu ghrishtam	Greenish black streak
2)	Abhraka (Biotite)	Sukhanirmochyapatram	Perfect cleavage and monoclinic crystal system (because of which it can be separated into thin layers)
3)	Sasyaka (Azurite)	Shikha kantha samachchayo	Hues of blue such as peacock
		Maha-ujjawalam	Metallic lustre
4)	Gandhaka (Sulphur)	Sukapicha samachchayo,	Yellow or greenish yellow colour
		Navneet samprabha, snighdha	Resinous or greasy lustre
5)	Haratala (Orpiment)	Swarna varna	Golden yellow colour
		Snigdha	Pearly or resinous lustre
		Tanupatra	Perfect cleavage and monoclinic crystal system
6)	Hingula (Cinnabar)	Japakusum varnabha	Red colour
		Mahaujjawalo	Adamantine lustre
		Bharapurna	Specific gravity 8.09
7)	Swarna (Gold)	Komala	Ductile and malleable property
		Guru	Specific gravity 19.3
8)	Manikya (Ruby)	Kusheshyadala chayam, Rakta utapala dala,	Pink to red colour
		Swacham	Transparent diaphaneity
9)	Praval (Coral)	Pakva bimbi phala chayam	Red colour corals
10)	Vajra (Diamond)	Vyudhita vibham , Snigdham,	Adamantine to greasy lustre
		Swachyam	Colourless
		Alekhyam cha vilekhanam	Hardness 10 (highest among minerals)
11)	Sphathikamani (Rock crystal/Quartz)	ghrishtam dhate swachatam purvatulyam	Hardness 7

		Swacha chayam	Colourless
12)	Godanti (Gypsum)	Patrachitam	Perfect cleavage and monoclinic crystal system
		Sharad indu sunirmalam	Colourless or white in colour
		Deepta prabham	Pearly lustre

Optical, Chemical and instrumental analysis for mineral identification:

For further confirmation of the mineral's identity or in case the physical properties of two minerals are similar, or if any confusion arises, their optical properties can be studied. Further if required, chemical tests or instrumental analysis can be performed for confirmation of the identity of the mineral or ore being studied.

The optical properties of minerals and ores are studied using a petrographic microscope. The transparent minerals are studied under plane polarised light and analysed (or crossed nicols) light. Whereas, the opaque ore minerals are studied under reflected light[30].

The most common chemical tests used for mineral identification are[31]:

- Acid test
- Flame test, etc.

Instrumental analytical techniques that can be used for mineral identification are as follows.[32 & 33] These analyses depend on the interest of the researcher.

- X-ray diffractometry (XRD)
- X-ray photoelectron spectroscopy (XPS)
- Scanning Electron Microscopy with Energy Dispersive X-Ray Spectroscopy (SEM/EDS)
- Electrochemical impedance spectroscopy (EIS)
- X-RAY Fluorescence (XRF)
- Ultraviolet-visible spectroscopy (UV-vis spectroscopy)
- Laser and (fast) chromatography
- Fourier transform infrared spectroscopy (FTIR)
- Dynamic light scattering (DLS)
- Transmission electron microscopy (TEM)
- Atomic force microscopy (AFM)
- Energy dispersive spectroscopy (EDS)
- Atomic absorption spectroscopy (AAS)
- Atomic Emission Spectrometry (AES)
- X-Ray Fluorescence Analysis (XRFA)

- Neutron Activation Analysis (NAA)
- Mass Spectrometry (MS)
- Beam (Position-Sensitive) Methods
- Secondary Ion Mass Spectrometry (SIMS)
- Laser Ablation Coupling Techniques (LA-ICP-AES, LA-ICP-MS)
- Proton Induced X-Ray Emission (PIXE)
- Gamma-Ray Emission (PIGE)
- Electron Microprobe Analysis (EMPA), etc.

Discussion:

This review explores integrating Ayurvedic identification methods (Grahya Lakshanas) with modern mineralogical techniques. While classical texts describe minerals qualitatively based on visual perception; advanced instrumental methods allow for quantitative precision. The following insights on key minerals demonstrate the potential for bridging traditional knowledge with modern geology.

1. **Reasoning behind Metallic Luster of chief copper ores:** In ayurveda, Swarnamakshika (Chalcopyrite) is refered as the chief ore of copper. The metallic luster of Chalcopyrite, as well as that of Bornite, results from high copper content, enhancing their reflective properties. This feature also often results in mistaking Chalcopyrite for gold, earning it the label "fool's gold." However, it can be distinguished from gold by its greenish-black streak, in contrast to gold's metallic gold streak. Gold's malleability and ductility further contrast with the brittle nature of Chalcopyrite, highlighting the value of streak and malleability tests in mineral differentiation. These statements make it evident that identification using geological parameters along with grahya lakshanas is equally significant.

2. **Perfect Cleavage and Sheet Formation in Minerals:** Minerals exhibiting "perfect cleavage" can split along defined planes, forming thin sheets. This characteristic is especially pronounced in Biotite (Krishna Abhraka), which displays elastic tenacity—a property by which a thin sheet bends but returns to its original shape upon release. This quality of biotite can be correlated with the '*Sukha nirmochya patram*' told in Ayurvedic classics.

3. **Identification of Ruby's red color and visual perception limitations:** Ruby's red color (Manikya) arises from chromium content, which cannot be detected through physical appearance alone. Advanced techniques like Inductively Coupled Plasma Atomic Emission Spectroscopy (ICPAES) enable the detection and quantification of such elements. This combination of traditional knowledge and modern analysis allows for a more complete approach to identifying minerals with concealed elemental components.

4. **Identification of Corals and Sudha Varga Minerals:** Corals and many Sudha Varga minerals, having animal origins, require specialized identification techniques, as traditional geological methods may not fully apply. Expertise from zoology enhances the accuracy of identification for these biologically derived minerals. A practical chemical approach involves using hydrochloric acid (HCl); when poured on minerals with a calcium carbonate ($CaCO_3$) composition, effervescence occurs due to CO_2 release. This reaction aids in identifying these minerals when physical attributes alone are insufficient.

5. **Variations in Quartz and the Classification of Rock Crystal:** Quartz exists in many varieties, with Rock Crystal being a colorless form that aligns with the Ayurvedic Sphatikamani. This correlation between traditional and scientific classifications demonstrates how Ayurvedic descriptions can correspond to specific geological mineral varieties, allowing for a more integrated understanding.

6. **Identification of Sikta Varga dravyas:** Specific grahya lakshanas aren't mentioned for sikta varga dravyas in the classics. Though they can be identified using the physical parameters told in geology textbooks. One example is dugdhapashana (talc). Geologically, Talc can be identified by its hardness of 1(which is the least among minerals), pearly luster, and sectile tenacity.

7. Hardness and Streak Test Limitations: Certain minerals have a hardness higher than that of the porcelain streak plate used in streak testing, resulting in a colorless streak. This limitation underlines the importance of additional testing methods for hard minerals to ensure reliable identification.

8. Cost-Effectiveness and Role of Advanced Techniques: The use of Grahya Lakshanas and physical properties in mineral identification is both cost-effective and reliable, relying on basic geological knowledge and visual perception. When these methods are inconclusive, advanced tools such as petrographic microscope, instrumental analysis are invaluable in confirming mineral identities.

9. Incorporating Relevant Studies and Critical Analysis: This section consolidates findings from recent studies to highlight the interdisciplinary approach required for mineral standardization and validation.

- **Importance of correct identification for Standardisation of Ayurvedic raw drugs[34 & 35]:**

In the research study titled *"An Attempt to Standardize Swarna Makshika – A Mineral Drug of Ayurveda"* by Prem Shankar Pandey, they found that the sample taken for study was found to be chalcopyrite based on ayurvedic grahya lakshanas and physical parameters as per geology. Also, elemental analysis via Electron Probe Micro Analysis (EPMA) confirmed the presence of Fe (46%), Cu (<1%), and S (52%) confirming the chemical composition of chalcopyrite ($CuFeS_2$). However, the copper content in the sample taken for the study fell below the Ayurvedic Pharmacopoeia of India's (API) therapeutic threshold of 5%. This highlights the need for a rigorous integrated approach to ensure correct mineral identification and therapeutic efficacy.

- **Sasyaka and Tuttha: Natural vs. Artificial Forms[36]:**

The study "*Mineralogical Identification and Characterisation of Sasyaka – An Ayurvedic Drug"* by Prem Shankar Pandey, identified Sasyaka as the naturally occurring mineral Bornite (Cu_5FeS_4), whereas Tuttha, used as a substitute, is artificially synthesized as Chalcanthrite ($CuSO_4 \cdot 5H_2O$). Grahya Lakshanas and API mineralogical parameters were employed alongside EPMA, which confirmed iron, copper, and sulfur as major components of Bornite, aligning it with Sasyaka's description(sasyaka). However, the distinct chemical compositions of Sasyaka and Tuttha raise critical questions about the efficacy of medicines prepared with Tuttha in place of Sasyaka. This underscores the need for clear guidelines on substitutions in Ayurvedic pharmaceuticals to maintain therapeutic integrity.

- **Resolving the Chapala Identity Controversy[37]:**

The study "*Chapala Nirnaya – An Experimental Study to Identify the Chapala*" by Prasanna Mathad et al. addressed the longstanding debate over whether Selenium or Bismuth should be considered as *Chapala*. By comparing the physical and chemical properties of these minerals with *Grahya Lakshanas*, Selenium emerged as the more accurate match. Furthermore, elemental analysis of chalcopyrite samples from copper mines across India consistently detected Selenium, confirming its proximity to copper ores, as described in Ayurvedic texts.

Conclusion:

This review article provides a comprehensive overview of the evolving landscape where traditional Ayurvedic knowledge intersects with modern geological and mineralogical sciences. It underscores the importance of collaboration, the need for accurate mineral identification, and the potential applications of advanced analytical techniques in preserving the efficacy and safety of Ayurvedic medications. This integrated approach can ultimately benefit both traditional Ayurvedic practitioners and modern science enthusiasts seeking to validate the authenticity of Ayurvedic remedies.

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