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Review Article

ALMANDINE GEMSTONE -A REVIEW

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ABSTRACT

Almandine garnet is ferrous iron end member of garnet group minerals. It is useful in making jewellery, sand blasting, glass polishing and as good abrasive. In addition, to the common physical and optical properties, some of the almandine garnets possess asterism, color zoning and alexandrite like effect. Its occurrence has reported from few countries only-India, Brazil, Canada, European Countries (Italy, Greece, Romania, Close to Paris, Yugoslavia), Hungary, Iran, S. Africa, Sri Lanka, UAE and USA. Chemical analysis has taken from literature and major oxides variations observed. From this, it is concluded that high concentration of SiO_2 present in Kothagudem (India) and Mozambique (S. Africa), Al_2O_3 in Mozambique and FeO in Chhattisgarh (India) and Garibpet samples. Island of Chios (Greece) and Val Codera (Italy) samples show high concentrations of MnO and MgO from Mozambique and S. Madagascar (S. Africa). CaO is high in Asakapalli area of Andhra Pradesh, India. As Almandine garnet is useful in many ways exploration for new deposits shall be carried out.

INTRODUCTION

The name garnet comes from the Latin granum, "grain", or granatus, "seed", because the majority is very tiny. Garnets are silicate minerals (Nesosilicates) and all species possess similar physical properties and crystal forms, but differ in chemical composition. All the minerals crystallize in the hexoctahedral class of the Isometric System and show Dodecahedra /Trapezohedra crystal habit (Figure 1).

Fig 1 Almandine garnet crystal

(Source: https://en.wikipedia.org)

The basic silicate structure unit is a SiO_4 group. The general chemical formula is $A_3 B_2 (Si O_4)_3$.

Members of the Garnet group and their chemical composition are as follows;

Almandine	$Fe_3 Al_2 (Si O_4)_3$
Andradite	$Ca_3 (Fe^{+3}, Ti)_2 (Si O_4)_3$
Grossular	$Ca_3 Al_2 (Si O_4)_3$
Pyrope	$Mg_3 Al_2 (Si O_4)_3$
Spessartine	$Mn_3 Al_2 (SiO_4)_3$
Uvarovite	$Ca_3 Cr_2 (SiO_4)_3$

USES

Garnets are useful in many ways (https://www.Minerals- .net) (https://en.Wikip edia.org). Some of the uses are explained here.

- Red Garnet gemstones (Almandine and Pyrope) are very affordable and faceted into all types of jewelry, including necklaces, rings, bracelets, and earrings.
- Round cabochons of red garnet are also popular and used in rings and bracelets Garnet sand is a good abrasive, and a common replacement for silica sand in sand blasting.

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- Mixed with very high pressure water, garnet is used to cut steel and other materials in water jets.
- Garnet sand is also used for water filtration media.
- The remaining garnet pieces that are finer than 200 mesh (74 micrometers) are used for glass polishing and lapping.

Keeping the various uses of Almandine Garnet in view the present study is aimed at reviewing its distribution and chemical analyses.

Almandine Garnet

Almandine (Fe_3 Al_2 $(Si$ $O_4)_3$), is the commonest ferrous end-member molecule in the garnet group and generally contain appreciable amounts of the Pyrope and Spessartine molecules. Which are the main constituents of the Earth's crust, upper mantle and transition zone. The physical and optical properties of Almandine garnet are shown in Table 1.

Table 1 Physical and Optical Properties of Almandine Garnet

Physical Property	Almandine Properties	Optical Property	Almandine Properties
Color	Purplish Red	Refractive Index	1.790 (+/-.030)
Crystal System	Cube	Pleochroism	None
Crystal Habit	Dodecahedra/ Trapezohedra	Ultraviolet Fluorescence	Inert
Fracture	Conchoidal	Transparency	Transparent to Translucent
Cleavage	None	Birefringence	0.000
Hardness	7-7.5	Dispersion	Weak
Specific Gravity	4.05 (+.25,-.12)	SR/DR/AGG	SR (ADR)
Streak	White	Phenomena	Asterism 4 and 6 ray, Alexandrite like effect
Luster	Greasy to vitreous	Inclusions	Silk, Crystals, Rutile needles, Zircon hallow
Morphol-ogy	Radial Cracks and voids	Zoning	Color and growth zoning

Distribution

Almandine garnets are reported from India, Brazil, Canada, European Countries (Italy, Greece, Romania, Close to Paris, Yugoslavia), Hungary, Iran, S. Africa, Sri Lanka United Arab Emirates and United States. Researchers studied various properties like Physical, Optical and Chemical and their studies are briefly presented (Table 2).

Table 2 Studies on Almandine Garnet from various Countries

Area and Authors	Work done
India Putrela, Krishna Dt., Andhra Pradesh Unpublished (Nazia sultana and P Sankara Pitchaiah)	Studying physical, optical and chemical properties
Garibpet, Telangana state Gilg *et al*., (2018)	Observed Inclusions and explained origin
Asakapalli Village, Visakha-patnam Dt., Andhra Pradesh Venkateswarulu *et al*., (2012)	Proved that chemical analysis can be done at any specific point of mineral
Sukhda tuff, Chhattisgarh Sarbani *et al*., (2008)	Identified almandine mineral
Southern Kerala Nandakumar and Suresh (1997)	Studied morphology of detrital garnet grains and interpreted their origin.
Khammam Dt., Andhra Pradesh Krishna Kumar *et al*., (1992)	Studied dielectric properties
Brazil Tocantins Krambrock *et al*., (2013)	Reported Color zoning, color changing and Alexandrite like effect
Canada Nova Scotia Allan and Clarke (1981)	Defined the textural groups based on crystal size, shape, inclusions and explained origin
European Countries Val Codera, Italy Diella *et al*., (2018)	Observed 3D distribution shape of inclusions and distribution of voids and cracks
Island of Chios, Greece, Mitropoulos *et al*., (1999)	Origin of almandine-spessartine garnets
Apahida, Romania Bugoi *et al*., (2016)	Based on the inclusions interpreted the origin
Saint-Denis Basilica, Close to Paris Calligaro *et al*., (2002)	Studied inclusions and identified five types of garnets
Slovenia, Yugoslavia Smit *et al*., (2014)	Analysed and compared with India and Sri Lanka garnets
Hungary Bihar County Eszter and Zsolt, (2011)	Identified the mineral and explained origin
Iran Sanandaj Sirjan Sepahi (2007)	Morphological and chemical studies
Dehsalm Complex Masoudi *et al*., (2006)	Growth zoning
S. Africa Chimoio, Mozambique Sangsawong *et al*., (2016)	Based on optical and chemi- cal properties identified Pyrope-almandine garnet
South Madagascar Martelat *et al*., (2012)	Studied P-T condition of garnet plasticity
Bekily in Madagascar Schmetzer *et al*., (2009)	Found that the ratio spessartine is the key feature to understand color changes
Lindy, Tanzania. Elizabeth (2008)	Identified the mineral as Almandine garnet
Umba valley, Tanzania Simmons and Falster (2007)	Reported Pyrope-Almandine
Roberts victors kimberlite pipe Bridget and Bass (1989)	Studied the non-monotonic elasticity composition behaviour exhibited by Ca bearing garnets
Sri Lanka Island of Sri Lanka Perera L.R.K (1984)	Studied chemical control cordierite almandine assemblage
United Arab Emirates Oman Mountains, Anke *et al*., (1993)	Reported radial cracks around quartz inclusions and interpreted their origin
United States Franklin County, Massachusetts Eric (2016)	Reported almandine and analyzed for inclusions and found apatite and mica
Province of western North Carolina Jason *et al*., (2013)	Studied weathering of almandine garnet
Wrangell Alaska Bull *et al*., (2012)	Measured mean squared displacement tensor precisely
Emerald Creek, Idaho Maxime *et al*., (2005)	Explained the origin of 4 and 6 ray asterism and micro structural factors
North Carolina Michael (1984)	Reported cause for natural weathering of almandine garnet

Details of Country wise studies on Almandine garnets are presented below

India

Nazia sultana and Sankara Pitchaiah have reported almandine garnet from Putrela, Krishna district, Andhra Pradesh (Unpublished) (Figure 2).

Fig 2 Almandine from Putrela

Gilg *et al*., (2018) demonstrated the engraved Almandine garnet gemstone from Garibpet deposit, Telangana State. Based on the inclusion characteristics the authors concluded that Early byzantine garnet engraved with a christian motif originated from this secondary deposit. Venkateswarulu *et al*., (2012) proposed a method for carrying chemical analysis at any specific point of the mineral. According to them variations can be summarized with the color and nature of the mineral group and crystal structure and lattice. Using Chemical Analysis, Sarbani *et al*., (2008) identified Almandine phenocrysts from Sukhda Tuff in the Precambrian Churtela Shale formation of the Chhattisgarh super group in Central India. Nandakumar and Suresh (1997) studied the morphology of Almandine Garnets from placer deposit of Manavalakurichi, Southern Kerala and reported the developed morphological patterns of detrital grains. They have observed the hierarchy and intensity of processes suffered by the grain. They have concluded that these garnet grains originated from chemical, mechanical and the mixed factors. Krishna Kumar *et al*., (1992) studied dielectric properties of Almandine Pyrope garnets from Kothagudem area of Khammam district in Andhra Pradesh and concluded that the estimated values of pure garnets are in good agreement.

Brazil

Krambrock *et al*., (2013) made a study on Purplish-red almandine garnets of Tocantins in Brazil. The study reported Color zoning, Color changing and alexandrite -like effect.

Canada

Allan and Clarke (1981) defined three textural groups of garnets based on their crystal size, shape, inclusion content and relationship to biotite. All garnets are almandine-rich, with 1.5-6.9% MnO. According to them garnets of textural Group I are considered of metamorphic origin and II and III are believed to be of igneous origin.

European Countries

Diella *et al*., (2018) studied Spessartine-Almandine garnets from Val Codera, Italy, using synchrotron X-ray computed micro-tomography. They have observed the 3D distribution and shape of inclusions, as well as the distribution of voids and cracks within the crystals. Mitropoulos *et al*., (1999) studied the origin of Primary Almandine -Spessartine -rich garnets from Island of Chios, Greece and attributed its generation to primary phases from a granite melt enriched in volatile constituents at low P-T. This granite melt could be the residual product of an un-exposed, earlier formed, typical back-arc granite of the area. Bugoi *et al*., (2016) made a study on inclusions in garnets of Apahida, Romania. The compositional results evidenced several types of garnets from the pyralspite series, suggesting distinct provenances for these Early Medieval gems. Micro PIXE results revealed the prevailing compositional type of garnets for each set of loose gems. Type II almandine was the dominant type found in Apahida II garnets. Calligaro *et al*., (2002) have identified five types of garnets from Saint-Denis Basilica, Close to Paris, corresponding to different deposits. Mineral inclusions were identified using μ-Raman spectrometry (apatite, zircon, ilmenite, monazite, calcite, quartz) present in almandine garnets. Smit *et al*., (2014) carried out the chemical composition of the Almandine garnet collected from the hilltop settlements in Slovenia (Yugoslavia) and reported them as I and II types.

Hungary

The authors revealed that the investigated gemstones are almandine and pyrope-almandine garnets (Eszter and Zsolt, 2011). They concluded that they may have been exploited from alluvial deposits.

Iran

Morphological and chemical studies of garnet crystal from Sanandaj Sirjan are analysed by Sepahi (2007). Masoudi *et al*., (2006) Studied growth zoning in Almandine-Spessartine garnets. They have concluded that zoning is formed by mineral growth during prograde regional metamorphism.

S. Africa

Sangsawong *et al*., (2016) reported the occurrence of Purple Pyrope-almandine garnet from Mozambique. They have carried out chemical analysis and observed the optical properties. Based on these, they have identified mineral as pyrope-almandine, commonly referred as Rhodolite garnet. Martelat *et al*., (2012) studied P-T condition of garnet plasticity in the continental crust using two feldspar thermometry GASP (Garnet-aluminosilicate-plagioclase) conventional barometry from South Madagascar. Schmetzer *et al*., (2009) Studied garnet from Bekily (Madagascar) and concluded that the ratio spessartine: (goldmanite + uvarovite) is the key feature to understand the color and color changes of garnets. Semi-quantitative measures of color change can be specified as faint, moderate, strong or very strong according to a combination of two fundamental parameters, i.e. hue angle difference and color difference. Elizabeth (2008) Identified the mineral occurred in Lindy area (Tanzania) as Almandine -Spessartine. In another study Simmons and Falster (2007) confirmed the garnets of Umba valley as Pyrope - Almandine. Bridget and Bass (1989) studied the Roberts victors Kimberlite pipe and concluded that the non-monotonic elasticity-composition behavior exhibited by Ca-bearing garnets in the grossular-andradites solid solution series is due to the substitution of transition metals for aluminum on the six-coordinated crystallographic site.

Sri Lanka

Perera (1984) studied the coexisting cordierite-almandine assemblage from Island of Sri Lanka and described politic metasedimentary rocks of the Precambrian granulite-facies terrain.

United Arab Emirates

Anke *et al*., (1993) studied almandine garnet of Oman Mountains in Arabian and reported radial cracks around quartz inclusions. According to their study the radial cracks are developed during uplift by the dilation of α-quartz (45vol%) without a phase transformation. The appearance of radial cracks depends on the initial inclusion pressure and the component of isothermal compressibility of the retrograde P-T path.

United States

Eric (2016) reported predominantly almandine, with some areas containing spessartine and minor pyrope. In Franklin country Inclusions of apatite, along with dark-colored mica (probably biotite) were also identified. Jason *et al*., (2013) Studied on weathering of Almandine garnet from North Carolina. According to him secondary surface layers formed by replacement of almandine garnet during chemical weathering. Surface layers are protective (PSL) consisting of goethite, gibbsite, and kaolinite yields excess Al for export during almandine garnet weathering. As the quantity of kaolinite present in the PSL decreases, the amounts of Al available for export increases. Bull *et al*., (2012) measured the meansquared-displacement (msd) tensor precisely of Wrangell Alaska garnets using Mossbauer spectroscopy. He concluded that while both effects contribute to the quadrupole asymmetries the Goldanskii Karyagin Effect is apparently predominant. Maxime *et al*., (2005) explained the origin of the 4 and 6 ray asterism and the microstructural factors of Idaho Purplish Red Garnets. Michael (1984) studied on natural weathering mechanism of North Carolina Almandine Garnet and observed the micro morphological evidences. They opined that oxidizing potential or the relative importance of organic and inorganic influences played a role in the local weathering environment.

Chemical Composition

Characteristically Almandine garnets contain high percentage of iron oxide compared to other members of the group. In addition to the iron oxide these garnets contain higher concentrations of SiO_2 and Al_2O_3. Considerable quantities of MnO, MgO and CaO are reported from various parts of the world. Other oxides like TiO_2, Na_2O, K_2O, Cr_2O_3, P_2O_5, V_2O_3 and H_2O may also present in minute concentrations. Chemical analysis of Almandine Garnets from various countries is given in tables 3a, 3b and 3c.

Table 3a Comparative study of Chemical analyses

Countries ➡	India				Brazil
Oxides (Wt%)	(1)	(2)	(3)	(4)	(5)
SiO_2	37.48	36.39	42.32	35±2	38.46
Al_2O_3	21.36	21.48	15.97	20±2	21.85
TiO_2	0.36	0.13	0.38	<0.1	-
FeO	28.96	36.31	30.40	45±7	29.22
MnO	0.34	0.80	0.33	1.3±0.3	4.54
MgO	3.78	2.73	3.56	<3	5.39
CaO	7.60	2.58	1.79	0.9±0.3	0.84
Na_2O	ND	-	1.88	-	-
K_2O	ND	-	0.67	-	-
H_2O^+	0.18	-	-	-	-
H_2O^-	0.07	-	-	-	-
Cr_2O_3	-	0.011	-	<0.1	-
P_2O_5	-	-	0.55	-	-
Fe_2O_3	-	-	1.7	-	-
V_2O_3	-	-	-	-	-

Table 3b Comparative study of Chemical analyses (continuation of 3a)

Count-ries ➡	Canada	European Countries		Hungary	Iran
Oxides (Wt%)	(6)	(7)	(8)	(9)	(10)
SiO_2	36.75 ±0.26	36.00	36.25	36.42	37.95
Al_2O_3	20.72 ±0.19	21.20	19.45	20.99	20.50
TiO_2	-	0.06	0.05	-	-
FeO	33.05 ±0.50	24.24	21.78	28.03	28.45
MnO	4.62 ±0.95	16.40	16.72	9.27	2.41
MgO	3.94 ±0.55	1.91	0.15	1.68	6.10
CaO	1.29 ±0.25	0.34	3.31	3.05	2.82
Na_2O	0.00	-	0.07	-	-
K_2O	-	-	-	-	-
H_2O^+	-	-	-	-	-
H_2O^-	-	-	-	-	-
Cr_2O_3	-	Bdl	0.00	-	-
P_2O_5	-	-	-	-	-
Fe_2O_3	-	-	2.13	3.11	1.97
V_2O_3	-	-	-	-	-

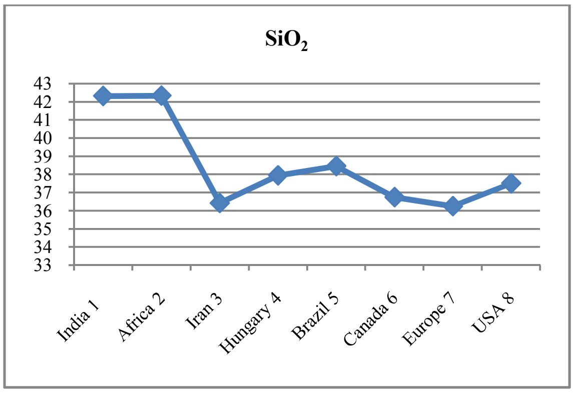
Table 3c Comparative study of Chemical analyses (continuation of 3b)

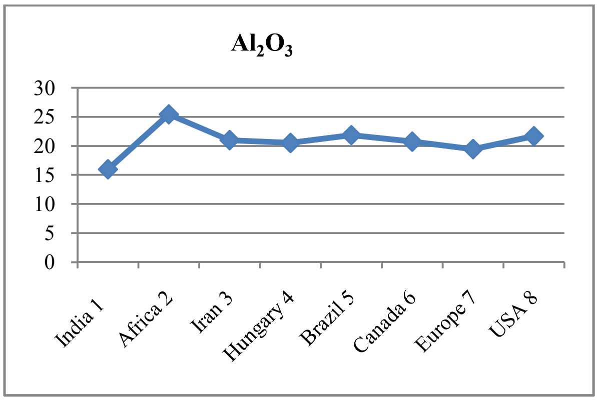
Countries ➡	S. Africa		United States
Oxides (Wt%)	(11)	(12)	(13)
SiO_2	42.34 ±0.33	39.39	37.51
Al_2O_3	25.41 ±0.22	22.64	21.66
TiO_2	-	0.00	0.10
FeO	17.93 ±1.31	25.70	31.16
MnO	0.22±0.02	0.27	3.54
MgO	13.16 ±1.19	11.68	4.95
CaO	0.94 ±0.20	0.40	1.78
Na_2O	-	-	-
K_2O	-	-	-
H_2O^+	-	-	-
H_2O^-	-	-	-
Cr_2O_3	-	0.08	0.02
P_2O_5	-	-	-
Fe_2O_3	-	-	-
V_2O_3	0.002 ±0.001	-	-

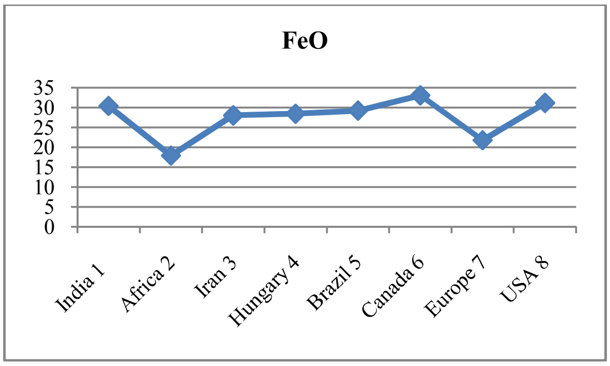
Source: 1. Asakap-alli area (Venkateswarulu *et al*., 2012), 2. Chhattisgarh (Sarbani *et al*., 2008) 3. Kothagudem (Krishna Kumar *et al*., 1992) 4. Garibpet(Rim) (Gilg Albert *et al*., 2018) 5. Tocantins state (Krambrock *et al*., 2013) 6. Nova Scotia (Allan and Clarke 1981) 7. Val Codera (Rim) (Valeria diella *et al*., 2018) 8. island of Chios, Greece (Mitropoulos *et al*., 1999) 9. Sanandaj sirjan (Sepahi, 2008) 10. Hajdu-Bihar County (Eszter and Zsolt 2011) 11. Mozambique (Sangsawong *et al*., 2016) 12. South Madagascar (Martelat *et al*., 2012) 13. Wrangell, Alaska (Bull *et al*., 2012).

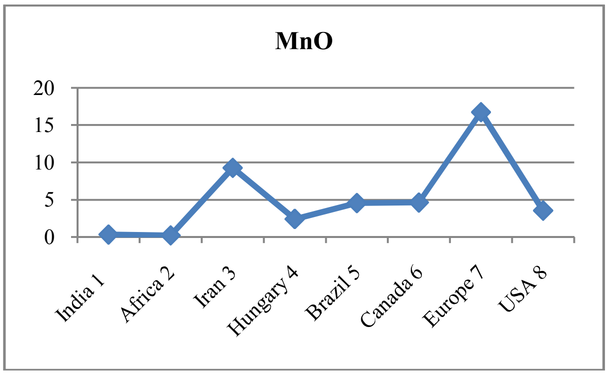
Variation of Oxides

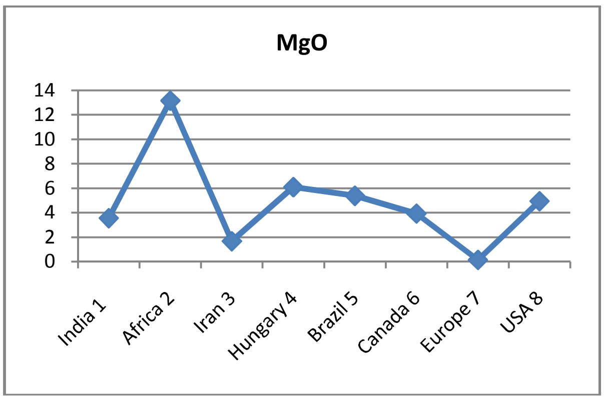
Some of the concentrations of major oxides are shown in Figure 3.











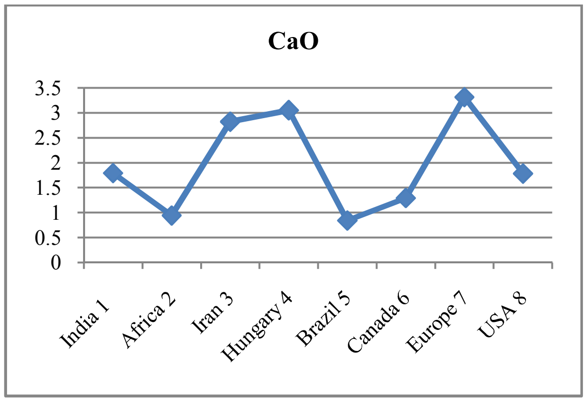


Fig 3 Variation of oxides from Almandine Garnets from various countries

Locations: 1.Kothagudem (India) 2. Mozambique (Africa) 3. Sanandaj sirjan (Iran) 4. Bihar County (Hungary) 5. Tocantins state (Brazil) 6. Nova Scotia (Canada) 7. Island of Chios, (Europe) 8. Wrangell, Alaska (United States).

The following observations are made from the chemical analysis (Tables 3a, 3b and 3c)

- High SiO_2 is observed in Kothagudem and Mozambique garnets and the lowest in Garibpet.
- High Al_2O_3 is present in Mozambique and the lowest in Kothagudem area.
- High FeO is noticed in Chattisgarh and Garibp*et Al*mandine garnets and the lowest in Mozambique.
- MnO is high in Island of Chios and Val Codera garnets and lowest concentration is recorded in Mozambique, South Madagascar, Kothagudem, Asakapalli, and Chattisgarh areas.
- High content of MgO is recorded in Mozambique and South Madagascar garnets and the lowest in Greece sample
- CaO is more in Asakapalli area of Visakhapatnam Dt. and the lowest concentrations are found in Val Codera, South Madagascar, Garibpet and Mozambique garnets.

CONCLUSION

Almandine gemstone looks beautiful and occurs at low price in the market. As such it can be called 'Poor Woman's gemstone'. It is reported from few world countries. If these gemstones occur in large quantities poor people can also wear Jewellery made of gemstones. Hence, it is suggested to explore new Almandine deposits worldwide to make it available in the market.

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References

Allan B.D. and D.B. Clarke (1981) Occurrence and Origin of garnets in the South Mountain Batholith, Nova Scotia, Canadian Mineralogist Vol. 19, pp 19-24.

Anke S.Wendt, Philippe D'Arco, Bruno Goffe and Roland Oberhansli (1993) Radial cracks around α- quartz inclusions in almandine: constraints on the metamorphic history of the Oman mountains, Earth and Planetary Science Letters, 114, pp 449-461.

Bridget O'neill and Jay D.Bass (1989) Elasticity of a Grossular-Pyrope-Almandine Garnet, Journal of

Geophysical Research, Vol. 94, NO. B12, pp 17,819-17,824.

Bugoi R., R. Oant_aˇ-Marghitu , T. Calligaro (2016) IBA investigations of loose garnets from Pietroasa, Apahida and Cluj-Somes_eni treasures (5th century AD, Nuclear Instruments and Methods in Physics Research B 371, pp 401-406.

Bull J. N., W. C. Tennant, T. Boffa Ballaran F. Nestola and C. A. McCammon (2012) Anisotropic mean-squared-displacement tensor in cubic almandine garnet: a single crystal 57Fe Mossbauer study, Phys. Chem. Minerals, 39, pp 561-575.

Calligaro T., S.Colinart, J.-P. Poirot, C.Sudres (2002) Combined external-beam PIXE and l-Raman characterisation of garnets used in Merovingian jewellery, Nuclear Instruments and Methods in Physics Research B 189, pp 320-327.

Diella Valeria, Rosangela Bocchio, Nicoletta Marinoni, Antonio Langone, Ilaria Adamo, Nicola Rotiroti (2018) The spessartine-almandine garnet from Val Codera pegmatite, Central Alps, Italy: a new insight on the crystallochemistry and a 3D image analysis of its inclusions, Rendiconti Lincei. Scienze Fisiche e Naturali https://doi.org/10.1007/s1 2210-018-0697-4.

Elizabeth Quinn Darenius (2008) Almandine-spessartine from Lindi, Tanzania, Gems &Gemology, Summer, Gem News Internat- ional, pp 165-166.

Eric S. Greene (2016) Almandine Garnet from the Red Embers Mine, Erving, Franklin County, Massachusetts, Rocks & Minerals, 91:5, pp 453-458.

Eszter Horváth 1 - Zsolt Bendő (2011) Provenance Study on a Collection of Loose Garnets from a Gepidic Period Grave In Northeast Hungary, Archeometriai Műhely 2011/1.

Gilg Albert H., Karl Schmetzer, and Ulrich Schüssler (2018) An Early Byzantine Engraved Almandine from the Garibpet Deposit, Telangana State, India: Evidence for Garnet Trade Along the Ancient Maritime Silk Road, Gems & Gemology, Vol. 54, No. 2, pp 149-165.

Jason R. Price, Debra S. Bryan-Ricketts, Diane Anderson And Michael A. Velbel (2013) Weathering Of Almandine Garnet: Influence Of Secondary Minerals On The Rate-Determining Step, And Implications For Regolith-Scale Al Mobilization, Clays And Clay Minerals, Vol. 61, No. 1, pp 34-56.

Krambrock K., F. S. Guimaraˆes, M. V. B. Pinheiro R. Paniago, A. Righi, A. I. C. Persiano J. Karfunkel, D. B. Hoover (2013), Purplish-red almandine garnets with alexandrite-like effect: causes of colors and color-enhancing treatments, Phys Chem Minerals, 40, pp 555-562.

Krishna Kumar K, V Balaram and Lalitha Sirdeshmukh (1992) Characterization and dielectric properties of almandine-pyrope garnet, Bull. Mater. Sci., Vol. 15 No. 3, pp 279-284.

Martelat J.-E., K. Malamoud, P. Cordier, B. Randrianasolo, K. Schulmann and J.-M. Lardeaux (2012) Garnet crystal plasticity in the continental crust, new example from south Madagascar, Journal of Metamorphic Geology, doi:10.1111/j.1525-1314.2012.009- 74.x.

Masoudi F., B. Mehrabi, and Sh. Mahmoudi (2006) Garnet (Almandine-Spessartine) Growth Zoning and Its Application to Constrain Metamorphic History in Dehsalm Complex, Iran, Journal of Sciences, Islamic Republic of Iran 17(3): 235-244.

Maxime J-F Guinel, M. Grant Norton, and David F. Bahr (2005) A Microscopy Study on the Origin of Asterism in Almandine-Pyrope Garnets, Microsc Microanal 11(Suppl 2), DOI: 10.1017/S1431927605502150.

Michael Anthony Velbe (1984) Natural weathering mechanisms of almandine garnet, Geology, Vol. 12, pp 631-634.

Mitropoulos P, A. Katerinopoulos and A. Kokkinakis (1999) Occurrence of primary almandine-spessartine-rich garnet and zinnwaldite phenocrysts in a Neogene rhyolite on the island of Chios, Aegean Sea, Greece, Mineralogical Magazine, August 1999, Vol. 63(4), pp 503-510.

Nandakumar V. and D.S. Suresh Babu (1997) Surface Features on Garnet from Different Sources: Observations from South Kerala, India, Journal Geological Society of India, Vol.50, pp 95-101.

Perera L.R.K (1984) Co-existing Cordeorite-Almandine-A key to the metamorphic history of Sri Lanka, Precambrian Research, 25 pp 349-364

Sangsawong Supharart, Victoria Raynaud and Vincent Pardieu (2016) Purple Pyrope-Almandine Garnet from Mozambique, Gems & Gemology, pp 321-323.

Sarbani Patranabis-Deb, Juergen Schieber & Abhijit Basu (2008) Almandine garnet phenocrysts in a ∼1Ga rhyolitic tuff from central India, Geol. Mag.: page 1 of 11. Cambridge University Press, doi:10.1017/S-001675680 8005- 293.

Schmetzer K., H.-J. Bernhardt, G. Bosshart and T. Hainschwang (2009) Color-change garnets from Madagascar: variation of chemical, spectroscopic and colorimetric properties, The Journal of Gemmology, 2009, Volume 31, No. 5-8, pp 235-282.

Sepahi A. A. (2007) Detailed Study of Morpho-logy and Chemistry Of Garnet Crystals With Suggestion Of New Subdivisions: Data From Pelitic Schists, Hornfelses and Aplites of Hamedan Region, Iran, Iranian Journal of Science & Technology, Transaction A, Vol. 31, No. A3.

Simmons William B. and Alexander U. Falster (2007) Pyrope-almandine from Tanzania, Gems & Gemology, Summer, pp 172-173.

Smit Z., H. Fajfar, M. Jersek, T. Knific, J. Lux (2014) Analysis of garnets from the archaeo- logical sites in Slovenia, Nuclear Instruments and Methods in Physics Research B, 328, pp 89-94.

Venkateswarulu P., K. Srinivasa Rao, C. Kasipathi, Y. Ramakrishna (2012) Multi- elemental analyses of isomorphous Indian garnet gemstones by XRD and external pixe techniques, Applied Radiation and Isotopes 70, pp 2746-2754.

https://en.wikipedia.org/wiki/Garnet\

https://www.minerals.net/gemstone/garnet_gemstone.aspx.

https://en.wikipedia.org/wiki/Almandine#/media/File:Almandinas.jpg.