Intaglio of a Cr-poor pyrope from Monte Suímo engraved with the bust of a Roman lady
1st century CE.
München, Staatliche Münzsammlung, inv. 2406.

GARNET MINES IN EUROPE

H. Albert Gilg and Jaroslav Hyršl

Transparent garnets were the most highly esteemed and valuable red gemstones in Antiquity and Early Medieval times from about 300 BCE to 700 CE, the so-called "Garnet Millennium"[1]. Theophrastos of Eresos, Aristotle's successor of the philosophical school in Athens and author of the first known mineralogical book *Peri Lithon* (On Stones), reported on the value of garnet, called *anthrax* ("charcoal") in Greek, in Hellenistic times: even a small stone was worth 40 gold staters weighing about 10 troy ounces[2]. He also mentioned seaports that delivered these precious stones: Carthage in Africa, Miletus in Asia Minor and Massalia in Europe.

Important manufacturing centers of garnet jewelry in Hellenistic times were certainly Alexandria[3] and Alabanda in Caria as noted by Pliny, but probably also some rich cities in Europe, such as Taras (Taranto) in Italy[4]. Archeological evidence indicates that Rome and Aquileia were important production sites of garnet jewels in Roman times[5], while the case of the Vesuvian cities Pompeii and Herculaneum with ateliers and abundant jewelry is less clear[6]. Asia certainly hosted other significant production sites during Hellenistic and Roman times. The Roman emporion (trading center) at Arikamedu near Pondicherry in India hosted a productive garnet bead manufacture[7]. In late Roman times, Byzantium-Constantinople and Treves (Augusta Treveriorum) were other main production sites of garnet jewels[8].

The use of garnet in art and jewelry declined somewhat afterwards and other red gemstones, like ruby, spinel or tourmaline became more appreciated, especially since Late Medieval and Renaissance times. Nevertheless, garnet remained a significant red stone in European jewelry throughout the centuries. In the 19th century, however, garnet experienced a revival in Biedermeier and Historicism

1. N. Adams, *The garnet millennium: the role of seal stones in garnet studies*, in Entwistle C., Adams N. (éds.), '*Gems of Heaven': Recent Research on Engraved Gemstones in Late Antiquity c. AD 200–600*, *British Museum Research Publication*, 177, The British Museum, London, 2011, pp. 10-24.

2. D. E. Eichholz, *Theoprastus, De Lapidibus*, Oxford, 1965.

3. J. Spier, *A group of Ptolemaic engraved garnets*, in *The Journal of the Walters Art Gallery*, 47, 1989, pp. 21-38.

4. E. M. M. De Juliis, *Gli ori di Taranto in età ellenistica*, Milano, 1984.

5. G. B. Andreozzi, G. Graziani, L. Saguì, *Gems from archaeological excavations at Rome (Crypta Balbi)*, in *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, 45/4, 1996, pp. 175-188 ; G. Tassinari, *La produzione glittica a Roma : la questione delle officine nel mondo romano in epoca imperial*, in *Rivista di Studi Liguri*, 74, 2008, pp. 251-317.

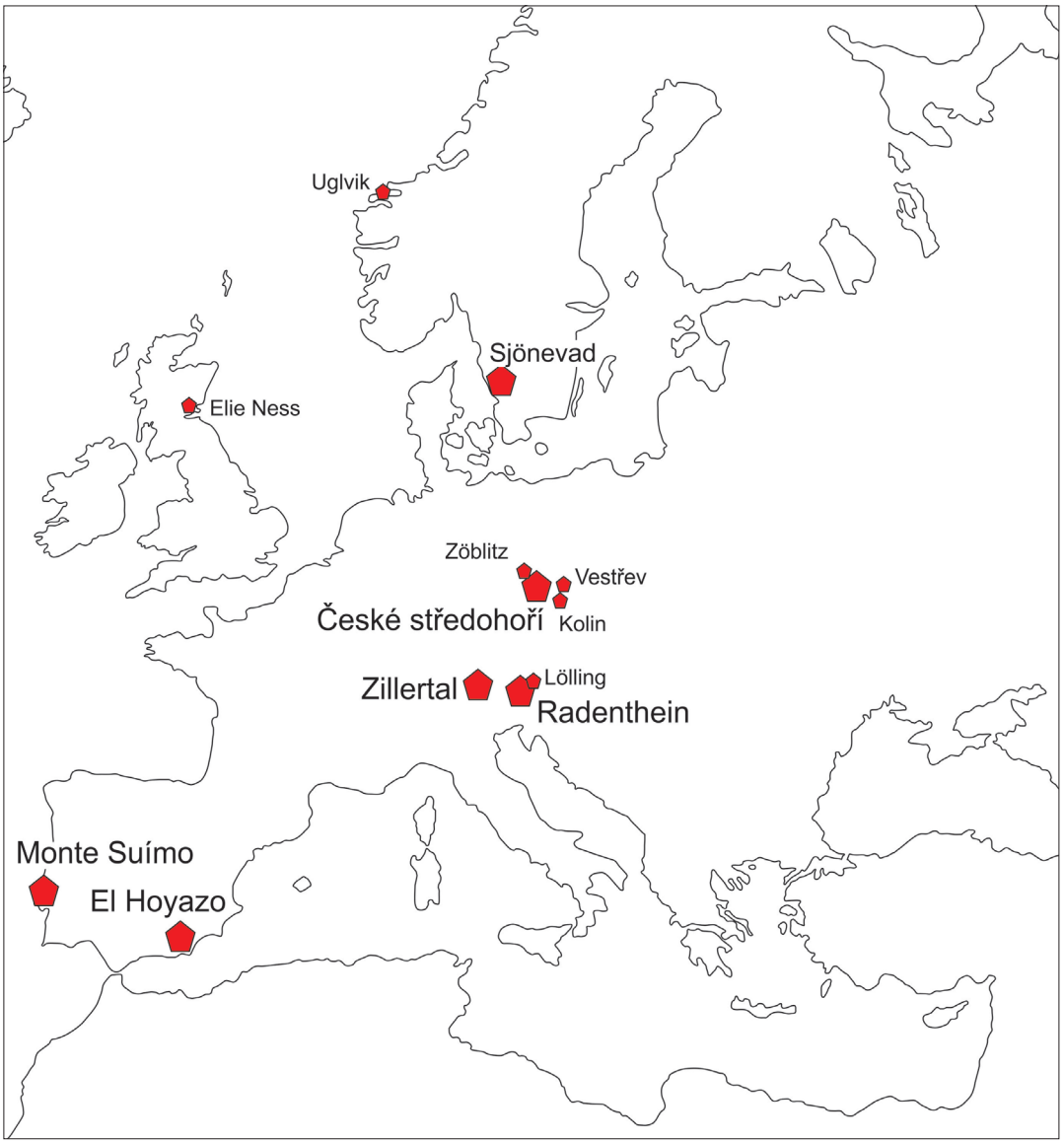
6. G. Tassinari, *Op. cit*.

7. P. Francis Jr., *Asia's maritime bead trade: 300 B.C. to the present*, University of Hawai'i Press, 2002.

8. B. Arrhenius, *Merovingian garnet jewellery, emergence and social implications.* Kungl. Vitterhets Historie och Antikvitets Akademien, Stockholm, 1985 ; J. Spier, *Antique and early Christians gems*, Wiesbaden, 2007.

jewelry with important production sites in Bohemia[9], the Black Forrest area[10] and Perpignan in southwestern France[11].

Today, almost all red gem garnets in the jewelry market come from Africa or Asia. The origin of garnets in old jewelry, however, is in most cases not known. Some progress has been achieved recently by using non-destructive, non-invasive and portable analytical methods. These studies revealed that many old red garnets came from India or possibly even from Africa, but some derived actually



Map of Europe with important red garnet deposits (large pentagons) and some minor occurrences of gem quality garnets (small pentagons)

9. R. Hanus, *Český Granat*, Granit Publ. Prague, 2013, 164 p.

10. R. Metz, *Edelsteinschleiferei in Freiburg und im Schwarzwald und deren Rohstoffe*, Lahr, 1961, 110 p.

11. L. Fonquernie, *Grenats de Perpignan : bijoux du Roussillon*, in *Société agricole, scientifique et littéraire des Pyrénées-Orientales*, 113, 2006, pp. 1-195.

from European deposits[12]. Europe is host to many garnet occurrences, although the majority is only of interest for collectors of mineral specimen, e.g. Ötztal, Austria. A few sites yielded sufficient quantities of gem quality stones to be exploited in a mine. Only one deposit in Podsedice, Czech Republik, is still in operation today.

This presentation summarizes the most important mining sites for gem garnets in Europe, shows the gemological and chemical characteristics of the stones and illustrates some arts objects with European garnets.

Monte Suímo, Portugal

Most probably the earliest account on garnet mining in Europe is recorded in Pliny the Elder's *Naturalis Historia* published in 77 CE[13]. After presenting all the deposits of the valuable fiery red gemstone (*carbunculus* in Latin, literally "little coal") in Africa, Asia Minor and India, he finally mentions a carbuncle deposit near Olisipo (Lisbon) referring to a certain Lusitanian writer Cornelius Bocchus. He states that the stones were extracted from the dry clayey soil with great labor. Garcia

Open pit of the large Roman garnet mine (mina grande) at Monte Suímo, Belas, Portugal, covered with maquis

12. N. Adams, *Op. cit.* ; H. A. Gilg, N. Gast, *Naturwissenschaftliche Untersuchungen an Granatgemmen der Sammlung James Loeb*, in C. Weiss, *Die Gemmen der Sammlung James Loeb. Forschungen der Staatlichen Antikensammlungen und Glyptothek* (Ed. F. Knauß), Supplement zu Band 1. Kunstverlag J. Fink, Lindenberg im Allgäu, 2012, pp. 48-57, 62-63.

13. D. E. Eichholz, *Pliny, Natural History*, Libri XXXVI-XXXVII, Vol. X, London, 1962.

Two tiny chromium-poor gem pyropes from Monte Suímo, Portugal (ant at right for scale)

da Horta, a Portuguese Renaissance physician, published a book describing all Indian medicinal substances including gemstones in Goa in 1563. He praises the abundance of Indian garnets and notes their low prices, but also mentions a deposit at Belas near Lisbon in Portugal. The garnet mining near Lisbon gradually declined and probably ceased in the 17th century[14]. Today two large open pits, the Mina Grande (Big Mine) with a length of 120 m, a width of 64 to 45 m and a depth of 27 m, and the Mina Pequena (Small Mine) with a length of 235 m, a width of 20 to 30 m and a depth of only 13 m, remain at Monte Suímo near Belas, Sintra province. Slightly orange, but clear pyropes occur as phenocrysts in an SW-NE trending alkali-basaltic breccia dike of Late Cretaceous age crosscutting Early Cretaceous sandstones and limestones[15]. The gemstones can reach a size of a few centimeters. The pyropes that crystallized in a magma chamber at mantle depth are characterized by relatively constant and high calcium and titanium, low manganese and variable magnesium and iron concentrations, but very low chromium contents, much less than 1000 ppm (see the table).

Chromium-poor pyropes of identical composition were used as jewelry, beads or engraved gemstones for finger rings in Late Hellenistic to Early Imperial Roman times[16] and in exceptional

14. P. Choffat, *Les Mines de Grenats du Suímo*, in *Comunicações da Comissão do Serviços Geológicos de Portugal*, 10, 1914, pp. 186-198. ; P. Azevedo, *As pedras preciosas de Lisboa (Belas) na História* in *Archeologo Português*, 23, 1916, pp. 58-202.

15. T. Palácios, *Petrologia do complexo vulcânico de Lisboa*, Unpublished doctoral thesis, Univ. Lisbon, Portugal, 1985, 260 p.

16. (H. A. Gilg, N. Gast, *Op. cit.* ; L. Thoresen, K. Schmetzer, *Greek, Etruscan and Roman garnets in the antiquities collection of the J. Paul Getty Museum*, in *Journal of Gemmology*, 33, 2013, pp. 201-222.

Ring
Gold. Chromium-poor pyrope engraved with Eros holding a lyre.
Hellenistic. 12.0 x 7.7 mm.
München, Staatliche Antikensammlungen und Glyptothek, inv. SL 632.

Bow-fibula
Containing over 200 individual garnets, only three of them are chromium-poor pyropes that most probably come from the Monte Suímo deposit. 7th century.
Wittislingen, Bavaria (Germany).
München, Archäologische Staatssammlung, inv. D 2014-196.

Merovingian jewelry, such as the votive crown of the Visigoth King Reccesuinth in the treasure of Guarrazar[17], the jewelry of the Frankish Queen Aregund in Saint-Denis[18] or the extraordinary bow-fibula from Wittislingen in western Bavaria.

El Hoyazo, Spain

The El Hoyazo volcanic complex near Níjar, Almería Province, SE Spain, is an Upper Miocene dacitic dome complex covered by reef limestone. The volcanic rock contains a great number of garnet-rich enclaves, but also single dodecahedral garnet crystals. A small gorge named "Rambla de las Granatillas" runs from interior of the weathered volcanic complex to the plain of Cuenca de Níjar and is covered with a red garnet-rich sand. The small alluvial fan deposit to the south of the gorge was mined for garnet in the beginning of the twentieth century until about 1933 and more recently since 1996 to about 2002 by a private company[19]. The garnet was used as an abrasives for sand blasting or sand papers. It is rich in iron, poor in calcium, but has variable manganese contents and often a strong internal zonation. Quartz, biotite, sillimanite, graphite, zircon, monazite, xenotime, and in the core frequently tiny rounded silicate glassy melt and aqueous-carbonic fluid inclusions were found as inclusions in the garnet. So far, no jewelry with garnets from El Hoyazo has been reported, but it is a potential source for small almandines in historic European jewelry.

Garnet-rich red sand from the Rambla de Granatillos, El Hoyazo volcano, Spain

17. M. F. Guerra, T. Calligaro, A. Perea, *The treasure of Guarrazar : Tracing the gold supplies in the visigothic Iberian peninsula* in *Archaeometry*, 49, 2007, pp. 53-74.

18. T. Calligaro, P. Perin, F. Vallet, J.-P. Poirot, *Contribution à l'étude des grenats mérovingiens (Basilique de Saint-Denis et autres collections du musée d'Archéologie nationale, diverses collections publiques et objets de fouilles récentes). Nouvelles analyses gemmologiques et géochimiques effectuées au Centre de Recherche et de Restauration des Musées de France*, in *Antiquités Nationales*, 38, 2007, pp. 111-144.

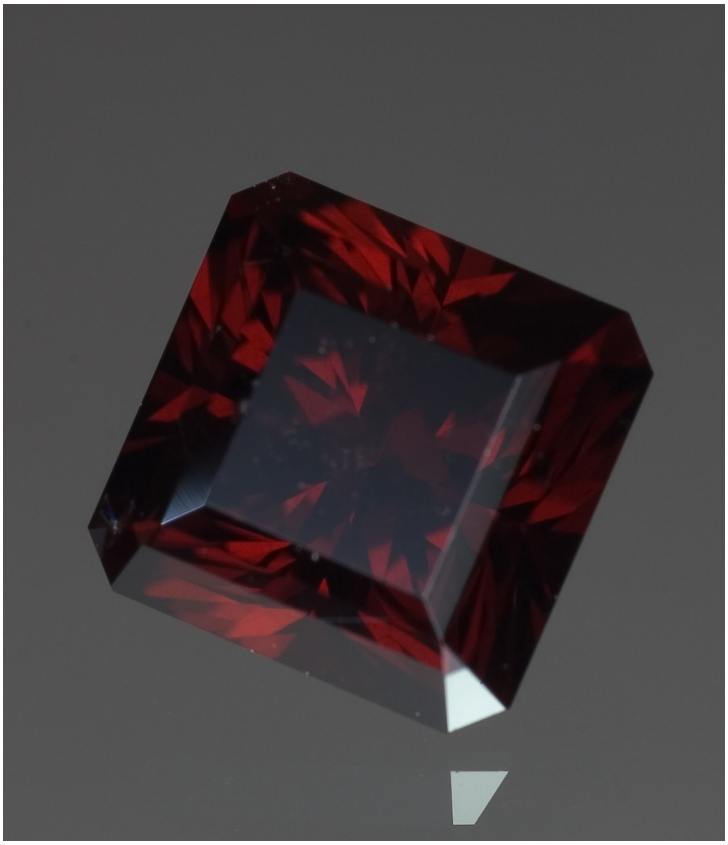
19. M.-J. Muñoz-Espadas, R. Lunar and J. Martínez-Frías, *The garnet placer deposit from SE Spain: industrial recovery and geochemical features*, in *Episodes*, 23, 2000, pp. 266-269.

Sjönevad, Sweden

Quarried garnet ores of the Sjönevad deposit, Halland, southern Sweden

During World War II between 1936 to 1937, garnet was mined for use as an abrasive from amphibolites of the Sveconorwegian Province near Sjönevad, Halland Province, southern Sweden. The Neoproterozoic metamorphic garnet crystals reach a diameter of more than 10 cm and show a distinct parting ("cleavage"). The garnets are Ca- and Mg-rich almandines with low manganese contents and inclusions of hornblende, ilmenite, apatite, rutile, quartz, zircon and carbonic fluid inclusions with chlorite and ankerite. Recently, beautiful facetted stones of 1.4 carat have been cut from this material. Mineralogical studies by Löfgren (1973) and Mannerstrand and Lundqvist (2003) showed that the abundant raw garnets and polished garnet platelets that were found at archeological excavations of Late Iron Age settlements in southern Sweden (Paviken, Slöinge, Valsta, Yngsjö) and Denmark (Gudme, Ribe) have similar chemical compositions as those from the Sjönevad deposit. We note, however, that garnet amphibolites are widespread in the Sveconorwegian Province and no evidence for early medieval garnet mining is preserved at Sjönevad. Thus other geologically similar occurrences in the region could have delivered the red stones. Nevertheless, since the 7th century a local garnet production for cloisonné jewelry certainly established in southern Sweden[20]. It is notable that garnets of this specific composition were not (yet?) found in Migration Period jewelry outside the Scandinavian realm.

20. J. S. Lundahl, *Röd Glöd – Granaternas betydelse under yngre järnålder med fokus på Gamla Uppsala*, BA thesis in Classical Archaeology and Ancient History, Uppsala University, 2011, 45 p.



Facetted gem-quality garnet (1.39 ct.) from the Sjönevad garnet deposit, Sweden

Vendel time button-on-bow-brooch from Gotland
Swedish garnet and mother of pearl.
När parish, Maldes, Sweden.

Zillertal, Tyrol, Austria

The Rossrugg ("horse spine") between Horn and Waxegg glacier, Zemmgrund, Zillertal, Austria
The prolific garnet mines were in the center of the picture at 2700 m above sea level.

Garnet crystals were first discovered in 1745 at the Rossrugg in the Zillertal area by Andrä Kreidl during chamois hunting. The garnets are hosted in a few decimeter to about a meter thick biotite-chlorite-schists that crosscut Upper Carboniferous tonalite gneisses in the Tauern Window. Andrä Kreidl soon started mining the site. Initially, the garnets were used as bullets for riffles. Later on their gem quality was recognized and gem garnet mining started in 1782. Today about 14 small deposits that experienced some open pit mining activity during last two centuries are known in the Schlegeis-, Zemm-, Gunggl-, Floiten-, Stillup- and Zillergrund valleys in Tyrol, Austria, but also in the adjacent Ahrntal in South Tyrol, Italy[21]. The deposits mostly occur in cliffy steep glaciated terrains at elevations ranging from 1800 up to 2700 m above sea level. The garnets were separated from the rock matrix in specific garnet tumble and stamp mills. Mining activity peaked in the 19th century and strongly declined before World War I. The garnets were used initially for local peasant jewelry, such as rosaries or chokers, and typically brought to Salzburg. But since 1805 they were allowed to be exported abroad, mostly to Bohemia, to be sold as "Bohemian" garnet as they show a similar deep red color. Most stones are less than a centimeter in diameter, but larger stones are known. The garnets are Ca- and Mn-rich strongly

21. W. Ungerank, *250 Jahre Zillertaler Granat*, in *extraLAPIS Nr. 12 - Zillertal (Das Tal der Gründe und Kristalle)*, München, 1997, pp. 12-17.

Bei den „Granatnern“ im Schwarzensteingrund (Tirol). Originalzeichnung von W. Püttner. (S. 268)
1. Granathütte und Stampfmühle. 2. Das Herunterbringen der Glimmerblöcke. 3. Inneres der Granathütte. 4. Rollmühle. 5. Zirbengruppe auf der Grawandalpe.

Garnet mining in the Zillertal
1. Garnet hut with stamp mill. 2. Hauling of ore from the mine in the cliffs.
3. Separating the gemstone from the ore. 4. Roll milling.
(Woodcut based on a painting by W Püttner).

Gem quality almandine garnet in biotite-chlorite schist from Rossrugg, Zillertal, Austria

A 19th century garnet jewelry with two ear rings and a brooch
While the small garnets most probably are Bohemian chromium pyropes,
the larger stones are probably almandines derived from an Austrian deposit in the Zillertal or Carinthia.

zoned almandines with very low Mg-contents[22]. They show a rich and deposit specific association of inclusion minerals, including ilmenite, rutile, apatite, epidote, quartz, biotite, chlorite, allanite, zircon, ankerite, dolomite, thorite, cerianite, graphite and aqueous two-phase fluid inclusions[23].

Radenthein, Carinthia, Austria

The garnet deposit at Laufenberg near Radenthein in Carinthia was discovered by Josef Hofer, a garnet mine owner from the Zillertal, by chance in 1854 during a pilgrimage to the nearby church of St. Erasmus in Nöring. He immediately claimed the area and started a mining operation that soon required underground exploitation with finally 3 adits and a shaft. The overall quality of the stones was, however, minor, the garnets were darker and had more inclusions that those from the Zillertal. Thus only a part was appropriate for jewelry, the rest was used as an abrasive. The stones were brought either directly to Bohemia or to Zell/Ziller to be mixed with Zillertal garnets. The mining activity faded soon after Hofer's death 1909. Most gem garnets occur in an unsual Eoalpine amphibolite-grade metamorphic rock of Austroalpine Radenthein Complex that is dominated by blue kyanite, black biotite and red garnet in proportions of 1:1:1, named "radentheinite"[24]. The garnets are characterized by very low calcium contents and moderate and zoned manganese concentrations and have inclusions of dominant short-prismatic rutile and characteristic tourmaline besides zircon, apatite and monazite[25].

Lölling, Carinthia, Austria

Garnets with a diameter of more than 10 centimeter occur in a contact zone of a serpentinite body in the southwestern most part of the Austroalpine crystalline basement complexes of the Plankogel unit in the Pusygraben near Lölling, Carinthia, Austria[26]. Although no traces of mining exist at this site, some spectacular objects have been carved from these garnets at the end of 18th and beginning of 19th century[27]. The famous garnet box in the Natural History Museum in Vienna was cut from a single crystal and has a size of 7 x 5 x 3 cm. The thickness of the walls is about 2.4 mm. The box is enchased in gold. The garnet contains characteristic large euhedral ilmenite inclusions and small short-prismatic euhedral apatites and has moderate pyrope and very low manganese

22. M. A. Leute, *Mineralogische Charakterisierung der Radentheiner und Zillertaler Schmuckgranate, Österreich*, Unpublished Diploma thesis, University Vienna, 2000.

23. *Ibid.* ; own observations.

24. R. Kaindl, R. Abart, *Reequilibration of fluid inclusions in garnet and kyanite from metapelites of the Radenthein Complex, Austroalpine Basement, Austria*, in *Schweizerische Mineralogische und Petrographische Mitteilungen*, 82, 2002, pp. 467-486.

25. M. A. Leute, *Op. cit.*

26. M. Riesco, K. Stüwe, J. Reche, *Formation of corundum in metapelites around ultramafic bodies. An example from the Saualpe region, Eastern Alps*, in *Mineralogy and Petrology*, 83, 2005, pp. 1-25.

27. G. Niedermayr, F. Brandstätter, *Die Dose aus Granat von der Saualp in der Edelsteinsammlung des Naturhistorischen Museums in Wien*, in *Carinthia*, II 187/107, 1997, pp. 573-581.

Garnet box made from a single almandine crystal from Lölling, Carinthia
Vienna, Natural History Museum, inv. A.y. 928.

contents[28]. This object is mentioned in the first inventory of the museum made between 1797 and 1806 by Andreas Stütz. The Staatliche Münzsammlung in Munich has a large collection of engraved gemstones including a large Medusa garnet cameo (5.0 x 4.7 x 1.7cm) and a huge garnet intaglio showing Hector's Farewell. The latter is one of the largest engraved gem garnet objects (8.4 x 5.6 cm) in the world. The stone was probably cut in Vienna by Christian Haupt and probably belonged to the collection of the Austrian banker Moritz von Fries[29]. The garnets of both objects are riddled with opaque ilmenite laths and short-prismatic apatite inclusions. Our chemical analyses using a portable X-ray fluorescence analyzer shows that the garnet is an almandine with moderate CaO (2-4 wt.%) and low MnO (<1.7 wt.%) contents, but has significantly high chromium concentrations (about

28. *Ibid.*
29. *Ibid.*

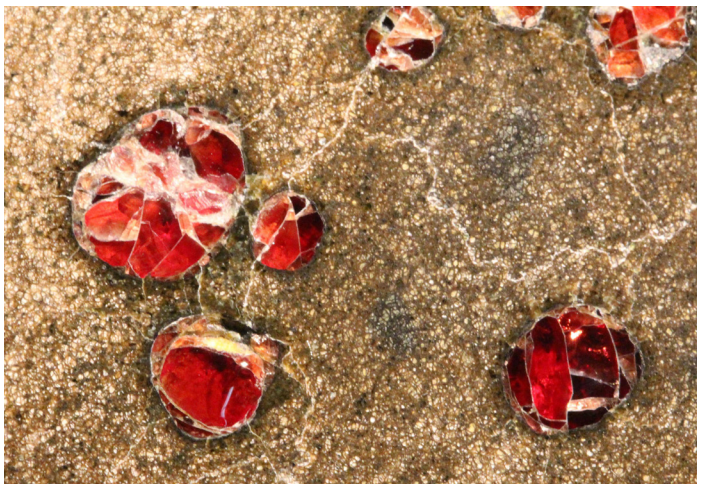
Hector's Farewell
A giant garnet intaglio with a length of 8.4 cm,
made from garnet from Lölling Carinthia, in the end of 18th or beginning of 19th century.
München, Staatliche Münzsammlung, inv. 1151.

500 to 900 ppm Cr_2O_3) that are characteristic of the Lölling garnets. The fist-sized garnets from the Pusygraben are now being used to construct the garnet room in the garnet museum "Granatium" in Radenthein.

Bohemia, Czech Republic

The most popular chrome pyropes come from the Czech Republic ("Bohemian garnets") but their size is limited to a diameter of 6 mm (approx. 1 ct), larger stones being extremely rare. There are three main Czech localities, two of them have been mined and one is of a historical importance only.

České středohoří area



Chrome pyropes in peridotite from Linhorka Hill

Active mining of Pleistocene gem pyrope-bearing gravel near Podsedice, České středohoří mountains, Czech Republic, in 2013

By far the most important localities are situated just under the southern slopes of the České Středohoří Mountains, about 70 km NNW of Prague[30]. The original source rocks are serpentinized garnet peridotites, more specifically lherzolites and subordinate dunites[31], hosted in microdiamond-bearing ultra-high pressure granulites[32] and only known from drill cores[33]. The red-violet to violet garnets in the dunites are characterized by high chromium contents (>5 wt. % Cr_2O_3) and are volumetrically a minor component of less than 1 vol. % of their host rocks[34]. In contrast, orange-red to red-violet pyropes in the lherzolites show lower chromium contents below 4 wt.%, but constitute to 6 to 14 vol.% of the ultramafic rock[35]. The garnet peridotites were brought to the surface mainly as xenoliths in diatremes during a Tertiary alkali-basaltic volcanic period[36]. The volcanic rocks and the garnetiferous xenoliths were weathered and the garnets resedimented in adjacent up to 6 m thick Pleistocene gravels that cover an area of about 70 km² situated to the west of Třebenice. The

30. J. Schlüter, W. Weitschat, *Bohemian Garnet – Today* in *Gems and Gemology*, 1991, pp. 168-173 ; A. V. Seifert, S. Vrána, *Bohemian Garnet*, in *Bulletin of Geosciences*, 80/2, 2005, pp. 113-124.

31. J. Fiala, K. Paděra, *The chemistry of the minerals in the pyrope dunite from borehole T-7 near Staré (Bohemia)*, in *Tschermaks Mineralogische und Petrographische Mitteilungen*, 24, 1977, pp. 205-219.

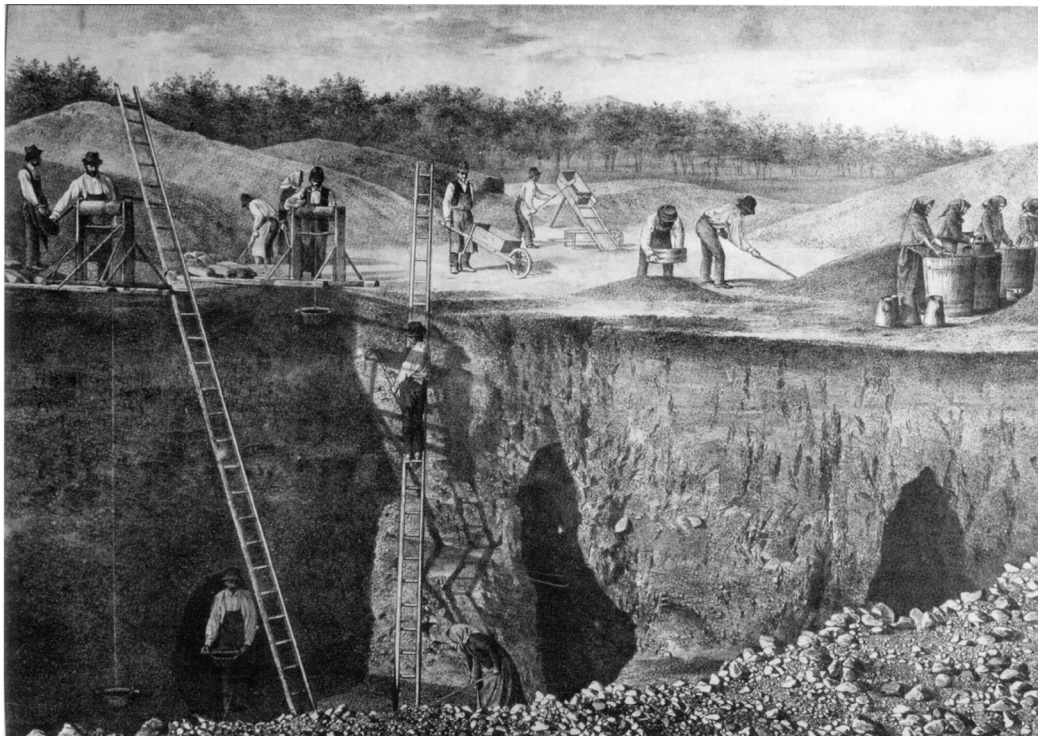
32. J. Kotková, P. J. O´Brien, M. A. Ziemann, *Diamond and coesite discovered in Saxony-type granulite: Solution to the Variscan garnet peridotite enigma*, in *Geology*, 39, 2011, pp. 667-670.

33. L. Kopecký, V. Sattran, *Buried occurrences of pyrope-peridote and the structure of the crystalline basement in the extreme SW of the České středohoří Mountains*, in *Krystalinikum*, 4, 1966, pp. 65-86.

34. J. Fiala, K. Paděra, *Op. cit.*

35. J. Fiala, *Pyrope of some garnet peridotites of the Czech Massif* in *Krystalinikum*, 3, 1965, pp. 55-74.

36. A. V. Seifert, S. Vrána, *Op. cit.*



Mining for garnets in Bohemia in the 19th century
Trebenice Museum.

heavy mineral concentrates from these gravels contain about 2.5 wt.% chrome pyrope[37] mostly derived from lherzolites. The garnets contain few inclusions, mostly very tiny complex crystallized melt inclusions with apatite, magnesite, graphite, olivine, Cr-spinel, a Fe-Ni sulfide, pargasite and clinopyroxene, but also olivine, clinopyroxene and zircon[38]. Garnets were collected initially on the surface of fields, but later they were mined from 5 m deep pits and side tunnels. The rarest types of mining were several shafts in primary peridotite-bearing vent breccia at Linhorka Hill near Staré and Granátový Hill near Měrunice. They reached a depth of more than 50 m.

Although gem garnet mining in Bohemia was first mentioned briefly in 1546 by Georg Agricola (*De Natura Fossilium*, p. 297-8), several archeological objects from the Migration Period contain Bohemian chrome pyropes. They come from sites in Sweden[39], France[40], Hungary[41], Southern

37. F. Novák, *Minerals of spinel group from pyrope-bearing gravels of the České středohoří Mountains, Czech Republic*, in *Journal of the Czech Geological Society*, 46, 2001, pp. 45-52.

38.J. Fiala, *Op. cit.* ; A. V. Seifert, S. Vrána, *Op. cit.* ; own observations.

39. O. Mellis, *Mineralogische Untersuchungen an Granaten aus in Schweden gefundenen Schmuckgegenständen der Merowinger- und Karolingerzeit*, in *Arkiv Mineral. och Geol.*, 3/15, 1963, pp. 297-362.

40. F. Farges, *Mineralogy of the Louvres Merovingian garnet cloisonné jewelry: Origins of the gems of the first kings of France*, in *American Mineralogist*, 83, 1998, pp. 323-330 ; T. Calligaro, S. Colinart, J.-P. Poirot, C. Sudres, *Combined external-beam PIXE and μ-Raman characterization of garnets in Merovingian jewellery*, in *Nuclear Instruments and methods B*, 189, 2002, pp. 320-32 ; T. Calligaro, P. Perin, F. Vallet, J.-P. Poirot, *Contribution à l'étude des grenats mérovingiens... op. cit.*

41. F. Brandstätter, G. Niedermayr, *Ein Beitrag zur mineralogischen Charakterisierung von Granaten in Schmuckstücken der Völkerwanderungszeit*, in *European Journal of Mineralogy*, 11/1, Beiheft, 1999, p. 40.

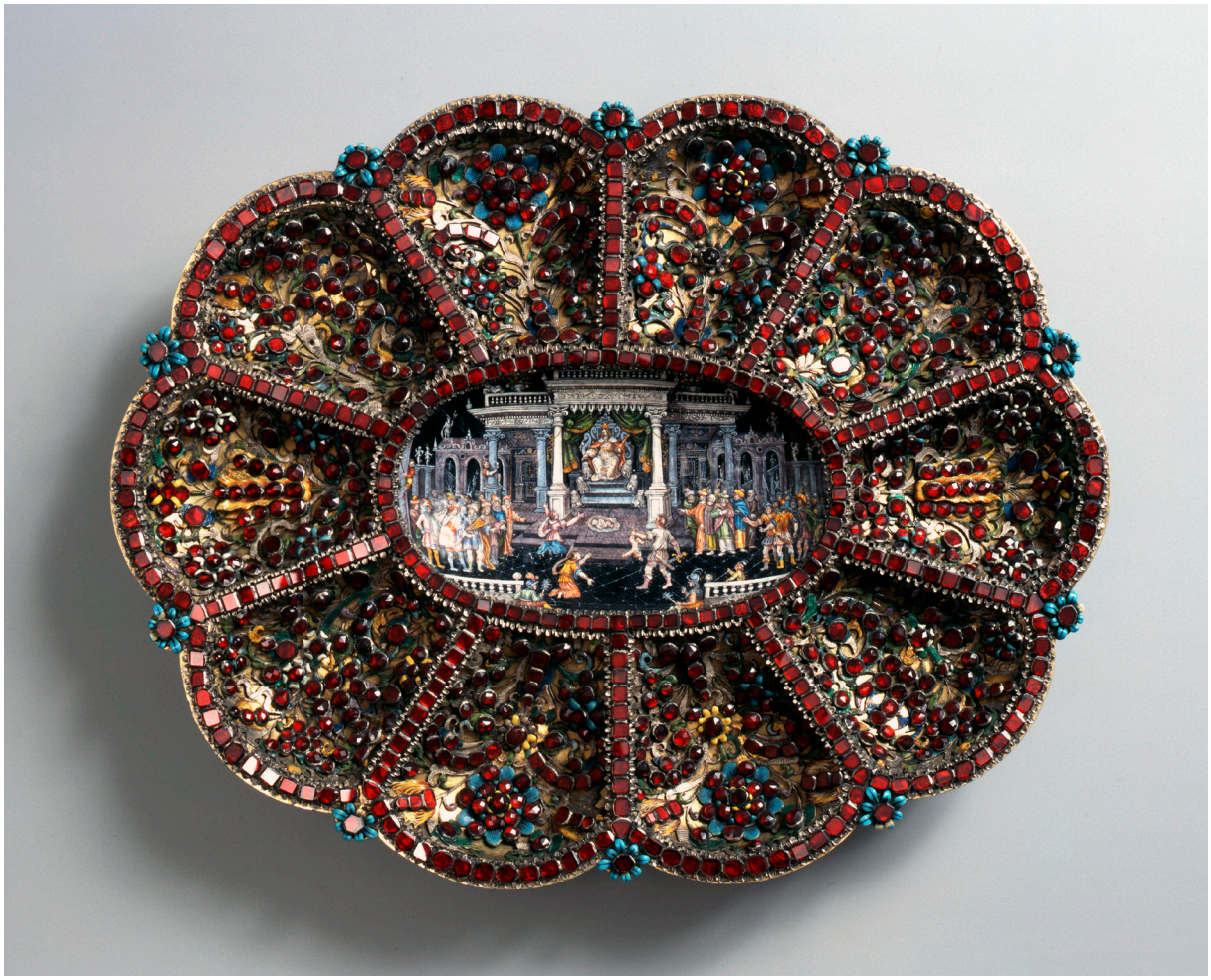
The Merching pendant in shape of a book (bible)
Bohemian chrome pyropes. 7th century.
München, Archäologische Staatssammlung, inv. GD 1999-599.

Germany[42] and England[43]. Most of the early medieval jewelry with chrome pyrope date from the 6th and 7th century CE. Ironically no chrome pyrope has yet been identified in Bohemian jewelry from that period. The term "Bohemian garnet" was used for the first time by Boetius de Boot (1609, *Gemmarum et Lapidum Historia,* later translated into French[44]), the personal physician of the emperor Rudolf II. He mentions their small size, beautiful color, resistance to fire and describes in great detail the price evaluation scheme based on the stone's diameter. Large stones were exceedingly rare and as valuable as true rubies. One of the oldest documents about garnets is from 1601, when

42. D. Quast, U. Schüssler, *Mineralogische Untersuchungen zur Herkunft der Granate merowingerzeitlicher Cloisonnéarbeiten*, in *Germania*, 78, 2000, pp. 75-96 ; H. A. Gilg, N. Gast, T. Calligaro, *Vom Karfunkelstein*, in L. Wamser (ed.), *Karfunkelstein und Seide*, Ausstellungskataloge der Archäologischen Staatssammlung, München, 37, 2010, pp. 87-100.

43. T. Calligaro, unpubl. report 2011.

44. A. Boece de Boot, *Le parfaict ioaillier ou histoire des pierreries : ou sont amplement descrites: leur naissance, iuste prix, moyen de les cognoistre, & se garder des contrefaites, Facultez medecinales, & proprietez curieuses*, Lyon, 1644.



Samuel Klemm,
Bowl of Solomon's judgment
Bohemian pyropes. Silver. Enamel. 1656. 32 x 25,5 x 4,6 cm.
Dresden, Staatliche Kunstsammlungen, inv. III 30.

the emperor Rudolf II gave rights to cut and polish Bohemian garnets to cutters in Freiburg and Waldkirch in the Black Forrest in Germany, some 500 km from the mines[45] ! The cutting of Czech garnets lasted there at least to the second half of the 18th century, when several cutting factories were established in Bohemia. The city of Turnov in northern Bohemia, with a centuries-long tradition of local agates cutting, became the center of the industry. The heydays of the garnet industry were the last two decades of the 19th century, when up to 10 000 people made their living just from garnets. The beginning of 20th century brought a sharp decline to the industry, but the garnet jewelry still remains quite popular in the Czech Republic, especially in tourist-oriented shops. The Granát Company, established in Turnov in 1952, is still producing garnet jewelry and they are also mining the last remaining productive locality at Podsedice, where garnet-bearing sediments are processed in a small concentration plant.

45. R. Metz, *Edelsteinschleiferei in Freiburg und im Schwarzwald und deren Rohstoffe*, Lahr, 1961, 110 p.

The size of Bohemian garnets was always very small as observed by Boetius de Boot in 1609. According to Bauer (1896), for one rough pyrope weighing 1.1 g with a diameter of 10 mm it was necessary to mine in average 2000 kg of smaller garnets. The central garnet in the „Order of the Golden Fleece", made in 1749, which is exhibited in the Grünes Gewölbe treasury in Dresden, was in the past described as the largest known Bohemian garnet. This stone measures 34 x 27.4 x 9 mm and is cut as a reverse bowl (hollow cabochon). Nevertheless, a new study showed the stone to be almandine, with a refractive index of 1.78 and a typical almandine optical spectrum. The largest real Bohemian pyrope is probably the smaller stone on the same object, measuring 21.5 x 19.8 x 5.2 mm[46].

Northern Bohemian area (mainly Vestřev)

There are several small occurrences of alluvial chrome pyropes in northern Bohemia. They originated from Permian sandstones but the original source peridotites were not found on the surface. By far the most important locality is Vestřev near Jičín, about 100 km ENE of Prague, where garnets were mined between 1994 and 2008 in the alluvium of the Olešnický creek. Several hundreds of kilograms of gemmy garnets were found during this period, even two small diamonds, and the locality will be probably reopened in a near future[47].

Kolín-Kutná Hora area

Several small garnet localities are known also near Kolín and Kutná Hora in central Bohemia, about 60 km E of Prague[48]. The garnets occur in Holocene river gravels and probably derived from the garnet peridotites in the Kutná Hora Complex[49]. The garnets were mined here just for a short time in the end of the 18th century, and they can be found only on several old jewelry objects[50]. The chrome pyropes are characterized by frequent inclusion of oriented rutile needles[51].

Zbyslav

A small locality between Zbyslav and Starkoč near Čáslav in central Bohemia yielded almandine grains to 7 cm in diameter. They are usually red-violet, only rarely deep red. They are transparent, but the grains are strongly fractured and only small stones can be cut. Almandine occurs there in a

46. J. Hyršl, *New gemmological study of large garnets of supposedly Czech origin*, in *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, 50, 2001, pp. 37-42.

47. R. Hanus, *Op. cit.*

48. S. Vrána, *Mineral inclusions in pyrope from garnet peridotites, Kolín area, central Czech Republic*, in *Journal of Geosciences*, 53, 2008, pp. 17-30.

49. S. W. Faryad, *The Kutná Hora Complex (Moldanubian Zone, Bohemian Massif): A composite of crustal and mantle rocks subducted to HP/UHP conditions*, in *Lithos*, 109, 2009, pp. 193-208.

50. J. Hyršl, *Gemmological study of so-called Kolín garnets and Bohemian garnets in the St. Vitus treasure*, in *Minerál*, 10, 2002, pp. 132-135 (in Czech).

51. S. Vrána, *Op. cit.*

Marek Hrbek,
Goblet
Bohemian garnets. Silver. Prague. 1673.
Écouen, Musée national de la Renaissance, inv. E.CL.20767.

Bohemian costume jewelry with Bohemian Cr pyrope (P), Zillertal almandine (A) and red Pb-rich glass (G)
19th century.
Munich, Sudetendeutsche Museum, inv. 3117.

biotitic gneiss and pegmatites[52], and the garnet rims may contain grains of kyanite, apatite or rutile. Birgit Arrhenius[53] considered them as a possible source of the Merovingian garnets, but it is highly improbable. They were found in a quarry, which was opened in the beginning of the 18th century and the locality is closed for a long time.

Zöblitz, Germany

The soft serpentinized peridotite of Zöblitz in the Erzgebirge, Germany, was used since the 16th century for carving of art objects, such as mugs, vessels, plates, goblets, etc. Locally it contains small red chromium pyrope crystals. During his tour to gem mining sites in Saxony, Wolf Caspar von Klengel, inspector of the cabinet of curiosities of the Elector, discovered the presence of small gem-quality pyropes in the small river between Zöblitz and Ansprung in 1659. The stones, however, are only very rarely larger than 5 mm in diameter like Bohemian pyropes. The chemical composition of Zöblitz pyropes is also very similar to Bohemian pyropes, but their manganese contents are a little bit higher than those of the Bohemian stones. However, very few garnets from Zöblitz were actually used in jewelry. The only approved object is the Breteuil or Teschen or Peace table, the master piece of the court jeweler Johann Christian Neuber. This giant "jewel" was given jointly by the Empress Maria Theresa and the Elector Frederick Augustus III of Saxony to Louis-August Breteuil for his effective mediation between Prussia and Austria after the War of the Bavarian Succession in 1779.

The Breteuil Table with a Zöblitz garnet (encircled) and Neuber's list of used gemstones
Breteuil, Château.

52. J. Cempírek, M. Novák, *Mineralogy of dumortierite-bearing abyssal pegmatites at Starkoč and Běstvina, Kutná Hora Crystalline Complex*, in *Journal of the Czech Geological Society*, 51, 2006, pp. 259-270.

53. B. Arrhenius, *Merovingian garnet jewellery, emergence and social implications. Kungl. Vitterhets Historie och Antikvitets Akademien*, Stockholm, 1985.

The table is in fact a "mineralogical journey" with 128 precious and semi-precious stones from Saxony including a faceted Zöblitz garnet with a diameter of 5 mm as unambiguously noted in the inventory list of Neuber[54].

Other occurrences

Gem quality chromium pyropes in ultramafic rocks do occur in the Western Gneiss Region of Norway, e.g. near Ugelvik on Otrøy island[55], and Cr-poor pyropes in alkaline basaltic rocks at the beach of Elie Ness, Fife, Scotland[56]. But both areas have never supplied significant amounts of gemstones to support a mining activity nor have yet been identified as a source of garnet in historical jewelry.

This short survey on mining sites for red gem garnets in Europe shows that the "old" continent had not only a long history of garnet jewelry manufacture since antiquity using red gemstones from distant countries in Asia and possibly Africa, but also a less well known long history of domestic gem mining. This was mostly centered in Portugal, Sweden, Bohemia and Austria. The first three sites certainly delivered gem quality garnets in Late Imperial Roman to Migration Period times, and the Monte Suímo deposit probably even earlier. It is yet unclear where the garnets came from that were - according to the notes of Theophrast and Pliny - traded in Massalia (Marseille) in antiquity. Recently, Noel Adams[57] suggested that Theophrast referred rather to Masaesylia in Numidia than the Phokaean colony in southern France. But this new interpretation opens new questions.

Chrome pyropes from the Bohemia and Ca-rich almandines from the Alpine deposits were major sources for the opulent European garnet jewelry of the 19th century. We note however that no scientific investigation on the composition of garnets in this kind of jewelry has yet been published. Recent analyses of a traditional costume jewelry from Bohemia with a handheld XRF device by the first author confirmed the presence of Bohemian chromium pyropes, a single large Zillertal almandine and many red glass stones[58]. Garnet from the important mines in Rajasthan in Northern India[59] have not yet been detected in 19th century European jewelry.

The chemical composition of major and trace elements and the mineral inclusions in garnets from European deposits are quite distinct (see table p. 169) and even discernible from those of Indian deposits. They can be used to infer the provenance of the red gemstones using mobile, non-destructive and non-invasive analytical techniques, such as hand-held X-ray fluorescence and Raman spectroscopy[60] including optical microscopy. Further provenance studies on gem garnets in historical jewelry are warranted.

54. K. Thalheim, *La table de Breteuil : parcours minéralogique en Saxe*, in A. Kugel (éd.), *« Le luxe, le goût, la science...». Neuber, orfèvre minéralogiste, à la cour de Saxe*, Saint-Rémy-en-l'Eau, 2012, pp. 300-333.

55. J. Hysingjord, *Edel granat fra Otterøy ved Molde*, in *Norges Geologiske Undersøkelse*, 255, 1967, pp. 5-9.

56. B. G. J. Upton, P. Aspen, R. W. Hinton, *Garnet pyroxenite xenoliths and pyrope megacrysts in Scottish alkali basalts*, in *Scottish Journal of Geology*, 39, 2003, pp. 169-184.

57. N. Adams, *Op. cit*.

58. We have analysed several objects and found that Bohemian pyrope, almandine from Austria and red glass was used for such jewelry (see page 166).

59. T. H. Hendley, *Garnets*, in *The Journal of Indian Art*, 1886-1916, Oct. 1886, pp. 1-16.

60. H. A. Gilg, N. Gast, *Op. cit.*

Garnet deposit	Chemical Composition (wt.%)						Inclusions	Host Rock	Temperature	Pressure	Age of Garnet Growth
	CaO	MgO	MnO	FeO	TiO_2	Cr_2O_3			[°C]	[kbar]	
Monte Suímo	5.2 - 5.9	15.0 - 18.1	0.3 - 0.5	10.6 - 15.3	0.37 - 0.47	0.00 - 0.11	-	Alkaline basaltic dike	1000 -1300 ?	>20 ?	Campanian, Cretaceous
El Hoyazo	0.7 - 1.4	2.0 - 4.6	0.5 - 6.2	34.7 - 38.7	0.01 - 0.14	0.00 - 0.02	bio,gra,sil,qtz,zrc,mon,MI,FI	Dacite, migmatic gneisses	790 - 900	5.0 - 7.0	Upper Miocene, Tertiary
Sjönevad	3.9 - 5.0	5.7 - 7.2	1.3 - 1.5	26.8 - 28.9	0.03 - 0.07	0.01 - 0.02	ilm,rut,hbl,apa,zrc,qtz,chl,ank,FI	Garnet amphibolite	660 - 770	7.5 -10.5	Neoproterozoic
Zillertal	2.5 - 11.2	0.9 - 4.4	0.0 - 5.8	23.7 - 36.1	0.01 - 0.22	<<0.01	ilm,rut,FI,zrc,apa,qtz,bio,chl,epi,ank,gra	Biotite-Chlorite Schist	550 - 600	9 - 11	Oligocene
Radenthein	0.4 - 2.1	0.6 - 7.1	0.1 - 2.8	32.1 - 34.3	0.00 - 0.21	<<0.01	rut,ilm,zrc,tur,FI,chl,apa,mon,qtz,pyr,xen,FI	Garnet-Kyanite-Biotite-Chlorit-Schist	560 - 590	5.5 - 7.5	Cretaceous
Lölling	2.3 - 6.7	2.4 - 4.2	0.5 - 1.8	36.0 - 38.4	0.06 -0.25	0.06 - 0.09	ilm,apa,cor,sta,dia,spi	Garnet-Corundum-Margarite-Chlorite-Schist	620	7.2	Cretaceous
České středohoří	4.2 - 5.5	19.3 - 21.3	0.0 - 0.4	7.4 - 9.3	0.17 - 0.73	1.48 - 4.21	MI,prg,spi,zrc,ol,cpx	Pleistocene gravel [Garnet peridotite]	890 - 1020	33	Visean, Carboniferous
Vestrev	4.3 - 4.6	19.6 - 21.6	0.0 - 0.4	6.9 - 8.8	0.39 - 0.60	1.45 - 2.66	TR,MI,ol	Holocene gravel [Garnet peridotite]	850 - 1000 ?	>30 ?	Carboniferous ?
Kolin	3.4 - 5.5	18.5 - 21.5	0.1 - 0.4	6.7 - 11.3	0.13 - 0.61	0.69 - 3.37	rut,MI,zrc,ol,cpx,opx	Holocene gravel [Garnet peridotite]	850 - 900	40	Carboniferous ?
Čáslav	0.8	4.8	2.2	33.3	?	?	kya,apa,rut	Biotite Gneiss, Pegmatite	>670	>14	Carboniferous
Zöblitz	4.0 - 4.5	19.9 - 21.3	0.3 - 0.5	7.7 - 10.0	0.30 - 0.66	1.51 - 1.67	?	Holocene gravel [Garnet peridotite]	865-1000	16 - 33	Visean, Carboniferous
Elie Ness	4.9 -5.5	17.9 -19.5	0.3 - 0.5	9.2 -11.6	0.34 - 0.62	0.01 - 0.25	-	Alkaline basaltic diatreme	1000 -1300	>20	Upper Carboniferous to Early Permian
Otrøy	2.5 - 6.6	15.6 - 22.1	0.3 - 0.6	6.9 - 11.7	0.00 - 0.10	0.78 - 5.12	ol,cpx,opx	Garnet peridotite	800 - 1500	32 - 65	Mesoproterozoic

Abbreviations: ank: ankerite, apa: apatite, bio: biotite, chl: chlorite, cor: corundum, cpy: clinopyroxene, dia: diaspor, epi: epidote-clinozoisite, gra: graphite, hbl: hornblende, ilm: ilmenite, kya: kyanite, mon: monazite, ol: olivine, opx: orthopyroxene, prg: pargasite, qtz: quartz, rut: rutile, spi: spinel, sta: staurolite, tur: tourmaline, xen: xenotime, zrc: zircon, FI fluid inclusions, MI: melt inclusions, TR: trichites (etch channels).

Chemical composition, inclusions of garnet, host rocks and conditions of crystallization (temperature, pressure, time)

Résumé

Durant l'Antiquité et le Moyen Âge, les grenats étaient les gemmes rouges les plus précieuses et les plus appréciées.

Si aujourd'hui presque toutes les gemmes rouges destinées à la bijouterie proviennent d'Afrique ou d'Asie, en ce qui concerne la provenance des grenats anciens, ce n'est que récemment que des avancées dans la connaissance ont été faites en utilisant des méthodes d'analyse non destructives et non invasives. Ils provenaient principalement d'Inde et d'Afrique. Mais l'Europe abritait également de nombreux gisements (Portugal, Espagne, Suède, Autriche, République tchèque, Allemagne). Le commerce des grenats se faisait alors notamment via les ports de Carthage, de Milet et de Marseille.

Ils étaient certainement mis en œuvre à Alexandrie et Antioche à l'époque hellenistique, mais probablement aussi dans de riches cités d'Europe, comme Tarante en Italie. Durant l'époque romaine tardive, Constantinople et Trèves étaient les principaux sites de production de bijoux en grenat.

Bien que son usage ait décliné dès la fin du Moyen Âge et à la Renaissance au profit des autres gemmes rouges (rubis, spinelles, tourmaline…), le grenat est resté une pierre significative dans la joaillerie européenne, surtout au XIX^e^ siècle (*revival*) en Bohème, dans la Forêt noire et à Perpignan.

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