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THE PERIODIC TABLE OF THE ELEMENTS AND THE ASSOCIATED MINERALS: GOLD

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ABSTRACT

Gold is a natural solid with a crystalline stable structure and exhibits an abundance of 0.04 ppm (mg/Kg) in the Earth crust. Gold, like silver, is one of the chemical elements less abundant in nature. Only palladium, tellurium, platinum, ruthenium, rhodium, osmium, rhenium, and iridium, present a smaller geochemical distribution. Because of its low chemical reactivity, the metal has very few minerals. This review presents a synopsis of the twenty nine (29) gold minerals known at the present time.

KEY WORDS: gold, mineralogy of gold, uses of gold.

RESUMO

O ouro é um sólido natural que apresenta estrutura cristalina estável e, que ocorre com uma distribuição geoquímica de apenas 0,04 ppm (mg/Kg) na crosta terrestre. Somente o paládio, o telúrio, a platina, o rutênio, o ródio, o ósmio, o rênio e o irídio apresentam uma distribuição menor. Isso se deve à baixa reatividade química do metal, responsável pela sua pouca representatividade na constituição dos minerais. Este trabalho apresenta uma rápida sinopse dos vinte e nove (29) minerais nos quais o ouro encontra-se presente, conhecidos até o momento.

PALAVRAS-CHAVE: ouro, mineralogia do ouro, uso do ouro.

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INTRODUCTION

Like silver, gold is one of the chemical elements less abundant in the Earth's crust. Only palladium, tellurium, osmium, rhenium and iridium have a lower geochemical distribution[1-3,16].

Gold (Au, from the Latin, *aurum*), is a soft, heavy, yellow metal that melts at 1064,43°C. It is the most malleable and ductile of all metals. Generally speaking, gold is chemically unreactive and is not attacked by oxygen or sulfur. It is not attacked by individual acids but, reacts readily with halogens or with solutions containing chlorine. For example, a mixture of nitric and hydrochloric acids (aqua regia) generating chlorine leads to the formation of auric chloride ($AuCl_3$). Gold dissolves in cyanide solutions in the presence of air or hydrogen peroxide to form $Au(CN)_2^-$. The reduction of solutions of $AuCl_4$ by various reducing agents such as $SnCl_3^-$, gives under suitable conditions highly colored solutions containing colloidal gold. Like silver, gold forms many alloys and some can be regarded as compounds, e.g. Cs^+Au^- and $AuTe_2$. Gold also forms many stable gaseous molecules like AlAu and NiAu[8-10].

As a metal of the Group 11 it has the following periodical properties: Z = 79; Symbol Au; A = 196.967 u; Atomic ray = 1.46 A^0; Ionic ray = 1.37 A^0; Eletronic configuration n = [Xe] $4f^{14}5d^{10}6s^1$; Melting point = 1,064 ^{0}C; Boiling point = 2,808 ^{0}C; Termal conductivity = 0.758 cal.cm/seg.^{0}C cm^{-2}; Electric resistivity 2.35 micron-ohm.cm at 20 ^{0}C; Oxidation states 0, I, III, and V; Reduction potential = 1.68 volts; and Density = 19.32 g $cm^{8,14}$.The industrial use of gold consists mainly of jewelry alloys (intermetallic alloys of Ag and Cu), international monetary standard, and electric contacts[8]. The most common gold minerals used as industrial sources are: native gold, calaverite, krennerite, nagyagite, petzite, and sylvanite[2]. Gold can also be obtained as subproduct of Cu-Pb-Zn mineralization. Other gold minerals are used for scientific purposes, and collections. Gold minerals are usually sulfides and similar compounds (14 species), intermetallic alloys (10 species), sulfossalts (4 species), and native element (1 specie). Its distribution in minerals are: silicates 0.0002 – 0.924 ppm; native elements (Ag, Pd, Pt, Cu, Te, As, Sb, S) 1000 ppm; sulfides and similar compounds 500 ppm; and jarosite $KFe_3(SO_4)_2(OH)_6$ 7900 ppm[1].

Although Au is sometimes found in small lumps or nuggets or in alluvial sands and gravels, it is more often associated with ores of silver, copper, lead and zinc. Gold is found in two major type deposits. Lode deposits are deposits where gold is found in cracks and veins in rocks. The second type of gold deposit is called a placer deposit. Placer deposits are formed when moving water eroded gold out of vein deposits or rocks-hosted disseminated gold. When the speed of water in the river slows down, the heavy gold falls to the bottom of the riverbed and accumulates in the sand and gravel. A third major source of gold is the recovery of the precious metal as subproduct of copper and silver mining[15].

The total amount of gold yet to be retrieved from the Earth is estimated at 100,000 tons. Republic of South Africa is the world's largest gold producer and holds about half of the reserves. The United States and Brazil possess significant amounts of the rest of the world's gold resources. About one fifth of the total resources of gold in the world is a component of copper and silver ores[1,2].

Gold in alluvial deposits is separated from the altered rocky matter, or sediment by washing with water. Because of its great density, gold sinks to the bottom while the earth deposits are washed away[22].

Mercury is used to remove the gold from ores by forming an amalgam from which mercury is subsequently distilled, The amalgamation process on an industrial scale was first developed in Zacatecas, Mexico by Bartolomé de Medina in 1555 for the extraction of silver[13].

Chlorine gas and sodium cyanide are also used to extract gold by different processes. Gold may be purified by electrolysis, as is the case with copper.

Gold is an element known, worked and appreciated by man since ancient times. It has always been considered a symbol of wealth and is cited repeatedly in the book of Genesis.

Apparently, the earliest mining activities occurred about 4000 B.C. in present day Romania and Bulgaria[9-13], inhabited at the time by the Thracians. Their refined taste for gold decorative objects is well attested by the Thesaurus of Pietroasa, Thesaurus of Sãncrãieni and the vast quantity of jewelry found in the tombs of Thracian kings near Vama and many other places in this part of Eastern Europe. The gold was obtained from mines in the Southern Carpathians (Transylvanian Alps) and the Mount Pangaion Region in Thrace. Unshorn sheepskin was used to recover gold dust from river sands on the shores of the Black Sea and this practice most likely 100 to the inspiration of the legend of the Golden Fleece[9-12].

During about the same period, extensive mining of gold also took place in ancient Egypt, particularly Nubia (present day Sudan). The Egyptians mastered the art of alloying gold with copper, the art of beating gold into leaf to extend its use and started casting gold using the lost-wax technique. The Egyptians cast and used the first standardized gold bars as means of payment and the Shekel, a coin originally weighing 11,3 grams became a standard unit of measure. It contained a naturally occurring alloy called *electrum* that was approximately two-thirds gold and one-third silver. As far as is known, Alchemy also originated later (about 300 B.C.) in Alexandria, Egypt and besides the elixir of long life and the philosopher's stone, the alchemists' main quest was to turn base metals into gold.

Most peoples throughout history adopted gold coins for their monetary systems. During the ancient times, we mention the Macedonians under Alexander the Great, the Romans and the Chinese. During more recent times, we cite the Arabs, the Italian (Florence, Genoa and Venice), England, France, Spain, the United States and many other countries. The best known golden coins were the Aureus (Rome), Ducat (Venice), Florin (Great Britain) and the Krugerrand (Republic of South Africa). Eventually, gold became a universal monetary standard[10].

During the Second Punic War with Carthage (202 B.C.), the Romans gained access to the gold mining region of Spain (*Saguntum*) and recovered gold from stream gravels and sands and by hard rock mining. At the end of the campaign in Gaul (58 B.C.), Julius Cesar brought back enough gold to give 200 coins to each of his soldiers and repay all of Rome's debts.

After the conquest of Dacia (present day Romania) by Emperor Traianus (106 A.D.), special attention was given to the mining of gold in the new province. The

mines became property of the Emperor and the Chief Mining Officer was called *Procurator Aurarium*. There were twelve mines in complete operation at the time, mostly in the Metaliferi Mountains, not far from the Dacian capital of *Sarmisegetusa* (*Ulpia Traiana*)[11,12]. The extraction of gold was done by crushing hard rock, followed by washing with water or by recovery from river sands.

The approximate gold consumption during the past years range between 100 and 1300 tons per annum. The greatest demand come from the carat jewelry and varies on the average between 800 and 1000 tons per year. The rest of the consumption of gold fabrication, in approximate numbers is as follows: electronics (100 tons), official coins (100 tons), dentistry and medicine (50 tons), metals, medallions, fake coins (15 tons) and other industrial and decorative uses (50 tons).

Gold and gold salts have been used from the treatment of rheumatoid arthritis. Gold alloyed with nickel has been employed in the production of heat resistant bronzing alloys for the aerospace industry. Gold coated visors area a standard safety feature for astronaut excursions and Col. Edward White made the first space walk during the Gemini Mission in 1965 using a gold coated visor to protect his eyes from direct sunlight.

The Mars Global Surveyor, launched in 1996 had on board a gold coated parabolic telescope that generated a detailed map of the entire Martian surface. Astronomers at the Keck Observatory in Hawaii used giant gold coated mirrors and obtained very detailed images of Neptune and Uranus in 2000. Gold coated compact discs were introduced in 1986. They provide perfection of reflective surfaces, eliminate pinholes common to aluminum surfaces to exclude any possibility of oxidative deterioration of the surfaces.

In 1960 AT&T Bell Laboratories was granted the first patent for the invention of the laser. The device used very well positioned gold coated mirror to maximize infrared reflection into the lasing crystal. Eight years later INTEL introduced a microship with 1,024 transistors interconnected with invisibly small gold circuits.

In 1970 a charge-coupled device was invented at Bell Telephone Laboratories. It was originally employed to record faint light from stars using gold to collect the electrons generated by light. At the present time, the device is used in hundreds of civilian and military devices, including home video cameras[10].

In 1971 the colloidal gold marker system was introduced by Amersham Corporation. It used tiny spheres of gold to mark or tag specific proteins in the human body.

The first space shuttle, launched in 1981 used gold coated impellers in its liquid hydrogen fuel pump.

A new gold alloy 990 Gold (1 percent titanium) was introduced to meet the need for an improved durability of 99 percent pure gold. The new alloy is very malleable, can be worked into intricate design, but can also be converted into a hard, durable alloy by simple heating in an oven.

Because of its scarcity and low reactivity, gold forms a small number of minerals. At the present there are only twenty nine (29) gold minerals recognized by the International Mineralogical Association (IMA)[4].

Two minerals have been validated only recently, the sulfosalt Museumite, Pb_5AuSb_{12} whose typical section is from the gold-tellurite deposit of Sãcãrâmb,

Hunedoara County, Metaliferi Mountains, Romania[39,40] and Novodneprite, $AuPb_3$, an intermetallic alloy, whose typical section is from Novodneprovsk, Kazakhstan[7,15].

The majority of gold minerals are sulfides (principally tellurides) and intermetallic alloy classes, originated by hydrothermal processes in ore veins[19].

The main gold producers on a global scale are: USA, Russia, Canada, and Republic of South Africa. The countries with major bulk reserves are: Brazil, Australia, People's Republic of China, and Russia. Brazil contains important auriferous deposites in Serra Pelada (Pará) and Alta Floresta (Pará and Mato Grosso States)[2,56].

GOLD MINERALS

1. Anyuiite $Au(Pb,Sb)_2$ – Tetragonal System; Native Elements and alloys-metals Class; (Mwt = 568.64 g/mol (D); 10.71% Sb, 54.66% Pb and 34.64% Au); Type locality: Bolshoi Anyu River Basin, Magadan Region, Russia; the name was proposed in reference to the Anyui river, a site where the mineral was firstly found. Paragenesis: mineral of dunite-harzgurgite rocks, associated with ilmenite, magnetite (rich in Ti), spinel (rich in Cr), hematite, pyrite, chalcopyrite and apatite. Principal occurrences: Russia, People's Republic of China, Poland, New Zealand and Australia[4,17].

2. Auricupride Cu_3Au – Cubic System; Native Elements and alloys-metals Class; (Mwt = 387.60 g/mol; 49.18% Cu and 50.82% Au); Type locality: Zolotaya Gora (Golden Mount) deposit, Karabash, Chelyabinsk, South Urals, Siberia, Russia; named after its composition of Au and Cu. Paragenesis: typical mineral of serpentinites, associated with barite, chalcopyrite, chrysocolla, copper, cuprite, native gold, lead, magnetite, pyrite, quartz, tetra-auricupride, titanite and ullmannite. Principal occurrences: Russia, Republic of South Africa, Chile, Czech Republic and Brazil (Jacuí-Bom Jesus da Penha, Minas Gerais)[4,5,18,19,31,].

3. Aurostibite $AuSb_2$ – Cubic System; Sulfide (Antimonide) Class; (Mwt = 440.47 g/mol; 55.28% Sb and 44.72% Au); Type locality: Giant Yellowknife mine; Northwest Territories, Canada; Pyrite group; named after its composition of Sb and Au. Paragenesis: mineral found in hydrothermal gold-quartz veins, in portions deficient in sufur and contain Sb minerals, associated with arsenopyrite, calcite, native gold, pyrite, quartz, stibinite, freibergite, jamesonite, bournonite, boulangerite, chalcopyrite, berthierite and native antimony. Principal occurrences: Canada, Czech Republic, Australia, Finland, Norway, France, Germany, Ghana, Zimbabwe, Russia, Kazakhstan, People's Republic of China, Republic of South Africa, Bolivia and USA[4,20,21].

4. Bezsmertnovite $Au_4Cu(Te,Pb)$ – Orthorhombic System; Sulfide (Telluride) Class; (Mwt = 1,002.89 g/mol; 6,34% Cu, 8.91% Te, 6.20% Pb and 78.56% Au); Type locality: Aginskoye gold deposit, Kamchatka Peninsula, Russia; the name is a homage

to the Russian geologists Marianna Bezsmertnaya (1915 - 1991) and Valdir Bezsmertny. Paragenesis: mineral of the cementation zone of a volcanogenic gold telluride deposit, associated with balyakite, bilibinskite, bogdanovite, chalcopyrite, native gold, quartz, sylvanite, native tellurium and tetrahedrite. Principal occurrence: Russia[4,23].

5. Bilibinskite $Au_5Cu_3(Te,Pb)_5$ – Cubic (?) System; Sulfide (Telluride) Class; (Mwt = 1,180.39 g/mol; 10.77 Cu, 21.62% Te, 17.55% Pb and 50.06% Au); Type localities: Aginskoye gold deposit, Kamchatka Peninsula, Russia; Dzhelambert, Kazakhstan; named is a homage to the Russian geologist Yuri Bilibin (1902 - 1952). Paragenesis: mineral of the weathering of gold-telluride deposits, associated with bezsmertnovite, bogdanovite, tellurides of Au, Cu, Pb and Fe, native gold, and replacing krennerite and sylvanite. Principal occurrences: Russia and Kazakhstan[4,24].

6. Bogdanovite (Au,TePb)3(CuFe) – Cubic System; Native Elements and alloys-metals Class; (Mwt = 592.69 g/mol; 3.20% Fe, 7.08% Cu, 21.53% Te, 34.96 % Pb and 33.23% Au); Type locality: Aginskoye gold deposit, Kamchatka Peninsula, Russia; named is a homage to the Russian geologist Aleksei Bogdanov. Paragenesis: mineral of the oxidation zone of Au-Te deposits, associated with bilibinskite, bezsmertnovite, chalcopyrite, gold, sylvanite, tellurium. Principal occurrences: Russia, Kazakhstan, Mexico and USA[4,25,26].

7. Buckhornite $AuPb_2BiTe_2S_3$ – Orthorhombic System; Sulfide (Telluride) Class; Sulfosalt; (Mwt = 1,171.74 g/mol; 17.83% Bi, 21.78% Te, 35.37% Pb, 16.81 % Au and 8.21 % S); Type locality: Buckhorn Mine, Jamestown, Boulder County, Colorado, USA; named after its locality. Paragenesis: occur in quartz-carbonate veins, associated with gold, pyrite and tetradymite. Principal occurrences: USA, Armenia and Czeh Republic[4,27].

8. Calaverite $AuTe_2$ – Monoclinic System; Sulfide (Telluride) Class; (Mwt = 452.17 g/mol; 56.44% Te and 43.56% Au); Type locality: Stanislaus Mine, Calaveras County, California, USA; named after its locality. Paragenesis: usually in veins of quartz of low-temperature; also in medium high-temperature deposits, associated with quartz, hessite, sylvanite, altaite, coloradoite, rickardite, arsenopyrite, tetrahedrite-tennantite, sphalerite, stibnite and fluorite. Principal occurrences: USA, Chile, Mexico, Canada, Russia, Japão, Australia, Fiji Islands and Phillipines[4,27].

9. Criddleite $TlAg_2Au_3Sb_{10}S_{10}$ – Monoclinic System; Sulfosalt Class; (Mwt = 2,549.18 g/mol; 8.02% Tl, 8.46% Ag, 47.76% Sb, 23.18 % Au and 12.58% S); Type locality: Golden Giant Mine and Page-Williams Mine, Hemlo Gold Deposit, Marathon, Ontario, Canada; the name is a homage to the English mineralogist Alan Criddle (1944-2002). Paragenesis: occurs in hydrothermal ore veins associated with arsenopyrite, aurostibite, gold, quartz, stibiconite, pyrite and fluorapophyllite. Principal occurrences: Canada and France[4,28,29].

10. Fischesserite Ag_3AuSe_2 – Cubic System; Sulfide (Selenide) Class; (Mwt = 678.49 g/mol; 47.69% Ag, 29.03% Au and 23.28% Se); Type locality: Predborice, Czech Republic; the name is a homage to Raymond Fischesser, Director of the National School of Mines, Paris. Paragenesis: occurs in carbonate veins in epithermal metal deposits, associated with acanthite, aguilarite, gold, naumannite, marcasite, calcite and baryte. Principal occurrences: USA, Argentina, Chile, Czech Republic, Canada and England[4,30,55].

11. Gold (Native gold) Au – Cubic System; Native Elements (Metals) Class; Copper Group; (Mwt = 196.97 g/mol; 100% Au); Type locality: unknown. Paragenesis: occur in hydrothermal quartz veins and placers deposits, associated with isomertieite, rucklidgeite, bismuthinite, sphalerite, bornite, platinum, arsenopalladinite, petzite, silver (electrum variety) and quartz. Principal occurrences: USA, Russia, Brazil, Romania and Republic of South Africa[2,4,15,22,34].

12. Hunchunite Au_2Pb – Cubic System; Native Elements (Intermetallic Alloys) Class; (Mwt = 556.58 g/mol; 9.69% Ag, 37.23% Pb and 53.08% Au); Type locality: Sandogou placer gold deposits of the Hunchun River, Hunchun, Jilin Province, People's Republic of China; named after its locality. Paragenesis: occurs in alluvial placers and hydrothermal ore veins, associated with anyuiite, gold, lead, alunite, andradite, atacamite, delafossite, pyrite, quartz, ferronickelplatinum and cuprite. Principal occurrences: People's Republic of China and Russia[4,32].

13. Kostovite $CuAuTe_4$ – Orthorhombic System; Sulfide (Telluride) Class; (Mwt = 770.91 g/mol; 8.24% Cu, 66.21% Te and 25.55% Au); Type locality: Chelopech, Bulgaria; the named is a homage to Bulgarian mineralogist Ivan Kostov. Paragenesis: occurs in gold and platinum-bearing replacement copper deposits, associated with gold, enargite, nagyagite, quartz, galena, petzite, hessite, pyrite, bornite, siderite, chalcopyrite and treasurite. Principal occurrences: Finland, Greece, Bulgaria, Mexico, USA and Uzbekistan[4,33].

14. Krennerite $(Au,Ag)Te_2$ – Orthorhombic System; Sulfide (Telluride) Class; (Mwt = 452.17 g/mol; 56.44% Te and 43.56% Au); Type locality: Sãcãrâmb, Hunedoara County, Metaliferi Mountains, Romania; the name is a homage to Hungarian mineralogist Joseph Krenner (1839-1920). Paragenesis: occurs in hydrothermal ore veins, associated with calaverite, colorodaite, gold, hessite, nagyagite, pyrite, sphalerite, sylvanite and quartz. Principal occurrences: Romania, Fiji Islands, Argentina, Australia, Finland, Canada, Hungary Japan, Mexico, Russia, Republic of South Africa and USA[4,35].

15. Maldonite Au_2Bi – Cubic System; Sulfide (Bismutite) Class; (Mwt = 602.91 g/mol; 34.66% Bi and 65.34% Au); Type locality: Maldon, Victoria, Australia; named after its locality. Paragenesis: found in gold-quartz vein of high temperature, intergrowth with gold and bismuth, associated with arsenopyrite, chalcopyrite, ferberite, galena, gold, sphalerite, pyrite and molybdenite. Principal occurrences: Australia, USA,

Canada, Republic of South Africa, Czech Republic, Finland, Romania, Russia, France, Greece, Japan, Marocco and Namibia[4,36].

16. Montbrayite $(Au,Sb)_2Te_3$ – Triclinic System; Sulfide (Telluride) Class; (Mwt = 739.12 g/mol; 8.24% Sb, 51.79% Te and 39.97% Au); Type locality: Robb-Montbray mine; Montbray Township, Québec, Canada; named after its locality. Paragenesis: coarsely crystalline masses, also found rimming gold grains, associated with altaite, calaverite, chalcopyrite, coloradoite, krennerite, melonite, petzite, quartz, ruckliedgeite, tellurobismuthinite and tetradymite. Principal occurrences: Australia, Canada, Finland, Mexico, Sweden and USA[4,37,38].

17. Museumite $Pb_5AuSbTe_2S_{12}$ – Monoclinic System; Sulfide Class; (Mwt = ? g/mol; 52.00% Pb, 10.68% Au, 6.16% Sb, 11.71% Te and 19.43% S); Type locality: Sãcãrâmb, Hunedoara County, Metaliferi Mountains, Romania; name is a homage to the museums of the world that preserve old samples. Paragenesis: mineral found in gold-telluride epithermal deposits of andesitic rocks, associated with nagyagite, calcite, coloradoite, hessite, petzite, quartz, sylvanite and rhodochrosite[6,32,33].

18. Muthmannite (Ag,Au)Te – Monoclinic System (?); Sulfide (Telluride) Class; (Mwt = 556.88 g/mol; 19.18% Ag, 46.51% Te and 34.31% Au); Type locality: Sãcãrâmb, Hunedoara County, Metaliferi Mountains, Romania. The name is a homage to German chemist Friedrich Muthmann (1861-1913). Paragenesis: occurs in intergrowths with krennerite, in epithermal hydrothermal veins, associated with nagyagite, tellurium, sylvanite, calcite, quartz and pyrite. Principal occurrences: Romania[4,41].

19. Nagyágite $(Te,Au)Pb(Pb,Sb)S_2$ – Monoclinic System; Sulfosalt Class; (Mwt = 1,059.12 g/mol; 4.93% Bi, 8.62% Sb, 30.12% Te, 19.56% Pb, 18.60% Au and 18.17% S); Type locality: Sãcãrâmb/Nagyág, Hunedoara County, Metaliferi Mountains, Romania; named after its locality. Paragenesis: occurs in epithermal hydrothermal veins, associated with calcite, krennerite, stutzite, muthmannite, alabandite, gold and petzite, and intergrowths with buckhornite in a quartz gangue containing tellurobismuthite, altaite, galena, calaverite and native gold. Principal occurrences: Romania, Argentina, USA, Armenia, Austria, Bulgaria, Canada, Czech Republic, Fiji Islands, Japan, Mexico, New Zealand and United Kingdom (Wales)[4,42,43].

20. Novodneprite $(AuPb_3)$ – Tetragonal System; intermetallic alloy; Type locality: Novodneprovskoe deposit, Northern Kazakhstan; named after its locality; Paragenesis: occurs in gold-arsenic-polimetallic deposit, associated with auricupride, bogdanovite, hunchunite, anyuiite, sorosite and yuanjiangite. Principal occurrence: Kazakhstan[7,15].

21. Penzhinite $(Ag,Cu)_4Au(S,Se)_4$ – Hexagonal System; Sulfide Class; (Mwt = 759.28 g/mol; 8.37% Cu, 42.62% Ag, 25.94% Au, 10.40% Se and 12.67% S)); Type locality: Sergeevskoe Au-Ag deposit, Penzhina River Basin, Kamchaktka Peninsula and Chukotka, Russia; named after its locality. Paragenesis: near surface Au-Ag deposit

in intergrowths with chalcopyrite, associated with aguilarite, galena and gold. Principal occurrences: Russia[4,37,44].

22. Petrovskaite AuAg(S,Se) – Monoclinic System; Sulfide Class; (Mwt = 339.25 g/mol; 31.80% Ag, 58.06% Au, 1.16% Se and 8.98% S); Type locality: Maikan ¨S¨ deposit, Pavlodar Region, Kazakhstan; the name is a homage to Russian mineralogist Nina Petrovskaia. Paragenesis: occurs like microscopic rims grains in gold deposits, associated with chlorargyrite. Principal occurrences: Kazakshtan and USA[4,45,46].

23. Petzite Ag_3AuTe_2 – Cubic System; Sulfide (Telluride) Class; (775.77 g/mol; 41.71% Ag, 32.90% Te, and 25.39% Au); Type locality: Sãcârâmb, Hunedoara County, Metaliferi Mountains, Romania; the name is a homage to chemist W. Petz who discovered the mineral in 1845. Paragenesis: occurs in hydrothermal ore veins of gold deposits, associated with native gold, hessite, sylvanite, krennerite, calaverite, altaite, montbrayite, melonite, frohbergite, tetradymite, rickardite, vulcanite, pyrite and quartz. Principal occurrences: Romania, USA, Australia, Uzbekistan, Russia, Kazakhstan, Canada, Chile, Fiji Islands and Phillipines[4,47].

24. Sylvanite $AuAgTe_4$ – Monoclinic System; Sulfide (Telluride) Class; (Mwt = 429.89 g/mol; 6.27% Ag, 59.36% Te and 34.36 Au); Type locality: Baia de Aries/Offenbanya, Metaliferi Mountains, Transylvania, Romania; named after the Province of Transylvania (Romania), place where the mineral was firstly found. Paragenesis: occurs in hydrothermal ore veins of low temperature, associated with petzite, native gold, fluorite, rhodochrosite, pyrite, acanthite, nagyagite, calaverite, krennerite and quartz. Principal occurrences: Romania, USA, Canada, Australia and Fiji Islands[4,41].

25. Tetra-auricupride AuCu – Tetragonal System; Native Elements (Intermetallic Alloys) Class; (Mwt = 260.51 g/mol; 24.39% Cu and 75.61% Au); Type locality: Sardala (Saar-Dala), Qingshui River, Malas (Marneshi) County, Xingjiang Autonomous Region, People's Republic of China. Tetraferroplatinum group; named after its crystallographie and Au-Cu contents. Paragenesis: occurs in mafic and ultramafic serpentinites containing platinoids, associated with Principal occurrences: People's Republic of China, Russia, France, Republic of South Africa and Switzerland[4,48].

26. Uytenbogaardite Ag_3AuS_2 – Tetragonal System; Sulfide Class; (Mwt = 584.70 g/mol; 55.35% Ag, 33.69% Au and 10,97% Au); Type locality: Tambang Sawah, Benkoelen District, Sumatra, Indonesia; the name is a homage to Duch mineralogist Willem Uytenbogaardt. Paragenesis: occurs in hydrothermal Ag-Au veins, associated with galena, acanthite, native gold (variety electrum), chlorargyrite, naumannite and quartz. Principal occurrences: Indonesia, Russia, USA, Bolivia, Argentina and Slovak Republic[4,49,50].

27. Weishanite $(Au,Ag)_{1,2}Hg_{0,8}$ – Hexagonal System; Native Elements (Intermetallic Alloys) Class; (Mwt = 925.26 g/mol; 8.74% Ag, 43.36% Hg and 47.90% Au); Type locality: Poshan Mine District, Weishan, Tongbai, Henan Province, People's Republic

of China; named after its locality. Paragenesis: occurs in silicified zone of silver-rich part of an Au-Ag deposit in biotite-granulite, associated with raspite, biotite, xenotime-(Y), acanthite, native gold, native silver, sphalerite, galena, pyrite and pyrrhotite. Principal occurrences: People's Republic of China, Brazil (Sumidouro, Minas Gerais) and Slovak Republic[4,51,52].

28. Yuanjiangite AuSn – Tetragonal System; Native Elements (Intermetallic Alloys) Class; (Mwt = 315.68 g/mol; 37.60% Sn and 62.40% Au); Type locality: Yuanjiang River, Yuanlin, Hunan Province, People's Republic of China; named after its locality. Paragenesis: mineral found in alluvial placers, associated with cassiterite, cinnabar, diamond, native gold, native osmium, native platinum, pyrite, realgar, rutile and zircon. Principal occurrence: People's Republic of China[4,53].

29. Zvyagintsevite (Pd,Pt,Au)3(Pb,Sn) – Cubic System; Native Elements (Intermetallic Alloys Class); (Mwt = 531.12 g/mol; 5.59% Sn, 54.10% Pd, 7.35% Pt, 29.26% Pb and 3.71% Au); Zapolyarnyi and Taymyrskii mines, Noril'sk Ni-Cu camp, Taymyr (Dolgano-Nenets autonomous district, Polar Siberia, Russia; the name is a homage to Russian geochemistry Orest Evegnevich Zvyangintsev, who studied the platinum resourches of Russia. Paragenesis: occurs in diferentiated gabbro-diabases intrusives, associated with hessite, molybdenite, tarkianite and Ag-Au alloys. Principal occurrences: Russia, Canada, Finland, Denmark (Greenland) and USA[4,54].

CONCLUSIONS

The small number of gold minerals (29 species described and validated by IMA - International Mineralogical Association) is related to the low chemical reactivity and geochemical distribution of the chemical element in the Earth Crust. Only native gold, calaverite, krennerite, nagyagite, petzite and the sylvanite are industrial sources of the metal that also can be obtained as a subproduct of the copper, lead and zinc sulfides.

The majority of gold minerals are sulfides, tellurides and intermetallic alloy classes, originated by hydrothermal processes in ore veins.

The main gold producers on a global scale are: USA, Russia, Canada, and Republic of South Africa. The countries with major bulk reserves are: Brazil, Australia, People's Republic of China, and Russia. Brazil contains important auriferous deposits in Serra Pelada (Pará) and Alta Floresta (Pará and Mato Grosso States).

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