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THE CHEMICAL ELEMENTS OF THE PERIODIC TABLE AND THE ASSOCIATED MINERALS – THE SILVER

Paulo César Pereira das Neves (Faculdade de Química)[1, 2]; Flávia Schenato (Faculdade de Engenharia do Meio Ambiente)[1, 2, 3], and Flávio Antônio Bachi (Faculdade de Geografia)[1]

[1]Laboratório de Geologia e Mineralogia; [2]Curso de Pós-Graduação em Ensino de Ciências e Matemática (PPGECIM); [3]Curso de Pós-Graduação em Energia, Ambiental e Materiais (PPGEAM)
Universidade Luterana do Brasil – ULBRA, Av. Farroupilha, 8001, Canoas/RS – nevespc@yahoo.com.br

ABSTRACT

Silver is a natural solid with a crystalline stable structure and exhibits an abundance of 0.04 ppm (mg/kg) in the earth crust. Silver thus, like gold, is one of the chemical elements less abundant in nature. Only palladium, tellurium, platinum, ruthenium, rhodium, osmium, rhenium and iridium, present smaller geochemical distribution. However, because of its lower chemical reactivity, the metal presents a low representative in mineral constitution. This review presents a synopsis of silver minerals (129 substances) as a contribution to the scientific knowledge of these substances.

KEY WORDS: silver, mineralogy of silver; use of silver minerals.

RESUMO

A prata é um sólido natural com estrutura cristalina estável que ocorre com uma distribuição geoquímica de apenas 0,04 ppm (mg/kg) na crosta terrestre. Juntamente com o ouro é um dos elementos químicos de menor abundância na natureza. Somente o paládio, o telúrio, a platina, o rutênio, o ródio, o ósmio, o rênio e o irídio apresentam uma distribuição menor. Isto se deve à baixa reatividade química do metal, responsável pela sua pouca representatividade na constituição dos minerais. Este trabalho apresenta uma rápida sinopse dos minerais em que a prata está presente (129 substâncias), constituindo-se numa contribuição ao conhecimento científico desses compostos.

PALAVRAS-CHAVE: prata, mineralogia da prata, uso dos minerais de prata.

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INTRODUCTION

Silver (derivate of the Latin *argentum*; and Greek *argyros*) is a metal known and worked by man for about 5,000 years. In the New World the first explored mines were in Zacatecas, Mexico, where the amalgamation process was developed by Bartolomé de Medina[1]. Like gold, silver is one of the chemical elements less abundant in the earth crust, with 0.04 ppm (mg/Kg). These elements are only more abundant than Pd, Pt, Te, Ru, Rh, Os, Re, and Ir. Besides its scarsity it combines with few chemical elements, because its low reactivity, thus forming a relatively small number of mineral compounds, 129 silver minerals validated until present by the IMA (International Mineralogical Association), including six new species characterized since 1999: baumstarkite, cuboargyrite, laforêtite, quadratite, sicherite, and tillmannsite)[2]. Five others species (giessenite, giraudite, incaite, tennantite, and tetrahedrite) validated before 1999[3] are not considered minerals contained silver anymore[2]. The silver is characteristically a white metal, very bulk, malleable, and ductile. Its periodical properties are: Z = 47; symbol = Ag; A = 107.87; electronic configuration: n = 5 [Kr] $4d^{10}5s^1$; Melting point = 962^0C; Boiling point = $1{,}955^0$C; and density = 10.5. The industrial use of silver consists in jewel alloys, component for looking-glasses, batteries, chemical catalysts, photographical emulsions, films, color-glasses, and medicine. The most usual silver minerals used as industrial sources are: acanthite, silver (native silver), and pyrargyrite; others, with minor importance are: aguilarite, argyrodite, bromargyrite, chlorargyrite, crookesite, dyscrasite, empressite, eucairite, freibergite, hessite, iodargyrite, jalpaite, miargyrite, naumannite, pearceite, petzite, polybasite, proustite, stephanite, stromeyerite, and sylvanite. Other silver minerals are used like scientific matter and collections. The majority of these compounds form sulfosalts (65 species); sulfides and similar compounds (tellurides, antimonides, and selenides) make up 45 species. Only few minerals like silver, eugenite, chlorargyrite, bromargyrite, boléite, bideauxite, argentojarosite, aurorite, and wheishanite are included in other chemical classes like native elements (intermetallic alloys), halides, oxides, and others.

The main goal of the present paper is a bibliographic compilation and the scientific divulgation of the knowledge about silver mineralogy. The crystallographic constants, physical properties and geological occurrences of silver minerals can be obtained trough the Mineral Data Site and references contained in these article.

SILVER MINERALS

1.Acanthite Ag_2S – Monoclinic System – Sulfide Class – (87.06% of Ag, and 12.94% of S). Name: comes from the Greek *akanta*, due to form of its crystals; argentite was proposed by Haidinger in 1868, and comes from the Latin *argentum* which means silver[2,4,5,6,7].

2.Aguilarite Ag_4SeS – Orthorhombic System – Sulfosalt Class - (79.53% of Ag, 14.55% of Se, and 5.91% of S). Name: homage to Mr. Ponciano Aguilar (1853-1935), Former-superintendent of the San Carlos Mine, Guanajuato (Mexico)[2,8].

3.Allargentum $Ag_{1-x}Sb_x$ (x = 0.009–0.16) - Hexagonal System – Sulfide - (98.87% of Ag, and 1.13% of Sb). Name: from the Greek for *another*, and the Latin *argentum*[2,9].

4.Andorite $PbAgSb_3S_6$ – Orthorhombic System – Sulfosalt Class - (12.36% of Ag, 41.85% of Sb, 23.74% of Pb, and 22.05% of S). Name: homage to the Hungarian mineralogist Andor von Semsey (1833-1923)[2,10,11,12,13].

5.Antimonpearceite $(Ag,Cu)_{16}(Sb,As)_2S_{11}$ – Monoclinic System – Sulfosalt Class - (61.02% of Ag, 11.98% of Cu, 8.61% of Sb, 1.77% of As, and 16.63% of S). Name: derivate for its compositional relationship to pearceite[2,3,14,15].

6.Aramayoite $Ag_3Sb_2BiS_6$ – Triclinic System – Sulfosalt Class - (34.99% of Ag, 11.3% of Bi, 32.91% of Sb, and 20.8% of S). Name: homage to Mr. Felix Avelino Aramayo, Former-director of the Companhia Aramayo de Minas (Bolivia)[2,16,17].

7.Arcubisite Ag_6CuBiS_4 - (?) System – Sulfosalt Class - (6.17% of Ag, 6.01% of Cu, 15.8% of Bi and 12.12% of S, with impurities of Fe 0.53%, Te 2.41%, and Pb 1.96%). Name: derivate of the Latin/German compositions: *argentum* (silver) + *cuprum* (copper) + *wismut* (bismuth) + *sulfur* (sulfur)[2,18].

8.Argentojarosite $AgFe_3(SO_4)_2(OH)_6$ – Trigonal System – Sulfate Class - (18.94% of Ag, 29.41% of Fe, 11.26% of S, and 39.33% of O). Name: derivate for its compositional relationship to jarosite[2,3,19].

9.Argentopentlandite $Ag(Fe,Ni)_8S_8$ – Cubic System – Sulfide Class – (13.21% of Ag, 11.02% of Fe, 14.37% of Ni, and 31.40% of S). Name: derivate for its compositional relationship to pentlandite[2,3,20].

10.Argentopyrite $AgFe_2S_3$ – Orthorhombic System – Sulfide Class - (34.16% of Ag, 35.37% of Fe, and 30.47% of S). Name: derivate for its compositional relationship to pyrite[2,21,22].

11.Argentotennantite $Ag_6Cu_4(Zn,Fe)_2(As,Sb)_4S_{13}$ – Cubic System – Sulfosalt Class - (43.56% of Ag, 8.55% of Cu, 5.28% of Zn, 1.5% of Fe, 12.1% of As, 6.56% of Sb, and 22.44% of S). Name: derivate for its compositional relationship to tennantite[2,3,23].

12.Argyrodite Ag_8GeS_6 – Orthorhombic System – Sulfide Class - (76.5% of Ag, 6.44% of Ge, and 17.06% of S, with impurities of Ga). Name: comes from the Greek *argyros* which means rich in silver[2].

13.Arsenpolybasite $(Ag,Cu)_{16}(As,Sb)_2S_{11}$ – Monoclinic System – Sulfosalt Class - (62.39% of Ag, 12.25% of Cu, 2.93% of Sb, 5.42% of As, and 17% of S). Name: derivate for its compositional relationship to polybasite[2,14,24].

14.Aurorite $(Mn^{2+},Ag,Ca)Mn^{4+}{}_3O_7.3H_2O$ – Trigonal System – Oxide Class - (8.12% of Ag, 48.23% of Mn, 2.01% of Ca, 1.52% of H, and 40.13% of O). Name: reference to the Aurora mine (USA)[2,25].

15.Balkanite $Cu_9Ag_5HgS_8$ – Orthorhombic System – Sulfide Class - (34.39% of Ag, 36.47% of Cu, 12.79% of Hg, and 16.36% of S). Name: reference to the Balkan Peninsula (Bulgaria)[2,26].

16.Baumhauerite-2a $Pb_{11}Ag(As,Sb)_{18}S_{36}$ – Monoclinic System – Sulfosalt Class - (51.38% of Pb, 24.77% (?) of Ag, As, Sb, and 23.85% of S). Name: homage to the German mineralogist Adolph Baumhauer (1848-1926)[2,27].

17.Baumstarkite $AgSbS_2$ – Triclinic System – Sulfosalt Class; (37.22% of Ag, 38.5% of Sb, 2.15% of As, and 22.13% of S). Name: homage to the German mineralogist Manfred Baumstark[2,16].

18.Benjaminite $Ag_3Bi_7S_{12}$ – Monoclinic System – Sulfosalt Class - (2.23% of Ag, 11.37% of Ag, 48.95% of Bi, 19.41% of Pb, and 18.03% of S). Name: homage to the American mineralogist Marcus Benjamin (1857-1932)[2,28].

19.Benleonardite $Ag_8(Sb,As)Te_2S_3$ – Tetragonal System – Sulfosalt Class - (65.74% of Ag, 4.64% of Sb, 19.44% of Te, 2.85% of As, and 7.33% of S). Name: homage to the American geologist Benjamin F. Leonard[2,23,29].

20.Berryite $Pb_3Bi_7(Ag,Cu)_5S_{16}$ – Monoclinic System – Sulfosalt Class - (8.91% of Ag, 5.25% of Cu, 48.34% of Bi, 20.54% of Pb, and 16.95% of S). Name: homage to the Canadian mineralogist Leonard Gascoigne Berry (1914-1982)[2,30].

21.Bideauxita $Pb_2AgCl_3(F,OH)$ – Cubic System – Halide Class - (16.21% of Ag, 0.08% of H, 62.26% of Pb, 15.96% of Cl, 1.2% of O, and 4.28% of F). Name: homage to the American mineralogist Richard August Bideaux (1935-2004)[2,31].

22.Billingsleyite $Ag_7(As,Sb)S_6$ – Orthorhombic System – Sulfosalt Class - (73.85% of Ag, 7.33% of As, and 18.82% of S). Name: homage to the American mineralogist Paul Billingsley (1867-1962)[2,32].

23.Bohdanowiczite $AgBiSe_2$ – Hexagonal System – Sulfosalt Class - (22.72% of Ag, 44.02% of Bi, and 33.26% of Se). Name: homage to the Polish geologist Karol Bohdanowicz (1864-1947)[2,33].

24.Boléite $KPb_{26}Ag_9Cu_{24}Cl_{62}(OH)_{48}$ – Cubic System – Halide Class - (8.88% of Ag, 0,36% of K, 13.94% of Cu, 0.44 of H%, 49.26% of Pb, 7.02% of O, and 20.1% of Cl). Name: homage to the locality of Boleo mine (Mexico)[2,33,34].

25.Borodaevite $Ag_5(Fe,Pb)Bi_7(Sb,Bi)_2S_{17}$ – Monoclinic System – Sulfosalt Class - (19.71% of Ag, 51.54% of Bi, 10.01% of Sb, and 18.75% of S). Name: homage to the Russian mineralogist Yuri Borodaev[2].

26.Bromargyrite $AgBr$ – Cubic System – Halide Class - (57.45% of Ag, and 42.55% of Br). Name after its chemical composition[2,4].

27.Cameronite $AgCu_7Te_{10}$ – Tetragonal System – Sulfide Class - (5.9% of Ag, 24.32% of Cu, and 69.78% of Te). Name: homage to the American economic geologist Eugene Cameron[2,35].

28.Canfieldite Ag_8SnS_6 – Orthorhombic System – Sulfide Class - (73.5% of Ag, 10.11% of Sn, and 16.39% of S). Name: homage to the American mining engineer Frederick Canfield (1849-1926)[2].

29.Capgarronite HgS.Ag(Cl,Br,I) – Orthorhombic System – Sulfide/Halide Classes. (?%). Name: reference to the Cap Garrone mine (France)[2,36].

30.Cervelleite Ag_4TeS – Cubic System – Sulfosalt Class – (72.99% of Ag, 21.59% of Te, and 5.42% of S). Name: homage to the French mineralogist Bernard Cerveille[2,37].

31.Chlorargyrite AgCl – Cubic System – Halide Class - (75.26% of Ag, and 24.74% of Cl). Name: after its chemical composition (Greek *chloros* = *pale green*; Latin *argentums;* Greek, *argyros*)[2,4,38].

32.Chrisstanleyite $Ag_2Pd_3Se_4$ – Monoclinic System – Sulfide Class - (25.36% of Ag, 37.52% of Pd, and 37.12% of Se). Name: homage to the British mineralogist Chriss Stanley[2,39,40].

33.Criddleite $TlAg_2Au_3Sb_{10}S_{10}$ – Monoclinic System – Sulfosalt Class - (8.46% of Ag, 8.02% of Tl, 47.76% of Sb, 23.18% of Au, and 12.58% of S). Name: homage to the English mineralogist Alan Criddle (1944-2002)[2,41].

34.Crookesite $Cu_7(Tl,Ag)Se_4$ – Tetragonal System - Sulfide Class - (2.87% of Ag, 16.29% of Tl, 47.28% of Cu, and 33.57% of Se). Name: homage to the English chemist Sir William Crookes (1832-1919)[2,23].

35.Cuboargyrite $AgSbS_2$ – Cubic System - Sulfosalt Class - (41.22% of Ag, 46.53% of Sb, and 5% of S). Name: alludes to the polymorphic relationship with miargyrite[2,42].

36.Cupropavonite $AgPbCu_2Bi_5S_{10}$ – Monoclinic System – Sulfosalt Class - (5.97% of Ag, 7.03% of Cu, 57.8% of Bi, 11.46% of Pb, and 17.74% of S). Name after its similarity with pavonite[2,43].

37.Danielsite $(Cu,Ag)_{14}HgS_8$ – Orthorhombic System – Sulfide Class - (28.31% of Ag, 41.7% of Cu, 13.16% of Hg, and 16.83% of S). Name: homage to the American mineral collector John L. Daniels[2,44].

38.Dervillite Ag_2AsS_2 – Monoclinic System – Sulfosalt Class – (60.81% of Ag, 21.12% of As, and 18.08% of S). Name: homage to the French mineralogist Prof. Dr. Henri Derville[2].

39.Diaphorite $Pb_2Ag_3Sb_3S_8$ – Monoclinic System – Sulfosalt Class - (23.8% of Ag, 26.86% of Sb, 30.48% of Pb, and 18.87% of S). Name: derivate from the Greek diaphora = *difference*[2,6,45].

40.Dyscrasite Ag_3Sb – Orthorhombic System – Sulfide Class - (72.66% of Ag, and 27.34% of Sb). Name: comes from the Greek meaning "bad alloy"[2,45,46].

41.Empressite AgTe – Orthorhombic System – Sulfide Class - (45.81% of Ag, and 54.19% of Te). Name: derivate from the Empress Josephine Mine (USA)[2,47,48,49,50].

42.Eskimoite $Ag_7Pb_{10}Bi_{15}S_{36}$ – Monoclinic System – Sulfosalt Class - (61% of Ag, 44.05% of Bi, 29.12% of Pb, and 16.22% of S). Name: homage to the Eskimos, the natives of the Greenland[2,13,51].

43.Eucairite CuAgSe – Orthorhombic System – Sulfide Class - (43.08% of Ag, 25.38% of Cu, and 31.54% of Se). Name: comes from the Greek for "opportunity", because it was discovered shortly after discovered of the Se[2].

44.Eugenite $Ag_{11}Hg_2$ – Cubic System – Native Elements - (70.76% of Ag, and 29.24% of Hg). Name: homage to the Austrian mineralogist Eugen Friedrich Stumptl[2,52].

45.Fettelite $Ag_{24}HgAs_5S_{20}$ – Trigonal System – Sulfosalt Class - (68.03% of Ag, 5.27% of Hg, 9.84% of As, and 16.85% of S). Name: homage to the German M. Fettel, a mineral collector[2].

46.Fischesserite Ag_3AuSe_2 – Cubic System - Sulfide Class - (47.69% of Ag, 29.03% of Au, and 23.28% of Se). Name: homage to the French mineralogist Raymond Fischesser[2,53].

47.Fizélyite $Pb_{14}Ag_5Sb_{21}S_{48}$ – Monoclinic System – Sulfosalt Class - (7.16% of Ag, 33.93 of Sb, 38.49% of Pb and 20.42% of S). Name: homage to the Hungarian mineralogist Sandor Fyzély[2,13].

48.Freibergite $Ag_6Cu_4(Fe,Zn)_2Sb_4S_{13}$ – Cubic System – Sulfosalt Class - (3.47% of Fe, 3.88% of Zn, 11.86% of Cu, 40.25% of Ag, 18.93% of Sb, and 21.6% of S). Name: reference from Freiberg, the site where the mineral was firstly found[2,3,4,45].

49.Freieslebenite $PbAgSbS_3$ – Monoclinic System – Sulfosalt Class - (38.87% of Pb, 20.24% of Ag, 22.84% of Sb, and 18.05% of S); compare with laffittite and marrite. Name: homage to the German mineralogist Johann Karl Freiesleben (1774-1846), mining commissioner of Saxony[2,54].

50.Furutobeite $(Cu,Ag)_6PbS_4$ – Monoclinic System – Sulfide Class - (?%). Name: reference to Furutobe Mine (Japan)[2,55].

51.Geffroyite $(Cu,Fe,Ag)_9(Se,S)_8$ – Cubic System – Sulfide Class - (3.74% of Fe, 12.78% of Cu, 43.4% of Ag, 35.3% of Se, and 4.78% of S). Name: homage to the French metallurgist Jacques Geffroy[2,3,56].

52.Gustavite $PbAgBi_3S_6$ - Monoclinic System – Sulfosalt Class - (9.51% of Ag, 55.27% of Bi, 18.27% of Pb, and 16.96% of S). Name: homage to the Danish chemist engineer Gustav Hageman (1842-1916)[2,57].

53.Hatchite $(Pb,Tl)_2AgAs_2S_5$ – Triclinic System – Sulfosalt Class - (12.30% of Tl, 12.98% of Ag, 18.03% of As, 37.40% of Pb, and 19,29% of S). Name: homage to the British geologist and mining engineer Frederick H. Hatch (1864-1932)[2,58].

54.Henryite $Cu_4Ag_3Te_4$ – Cubic System – Sulfide Class - (23.36% of Cu, 29.74% of Ag, and 46.90% of Te). Name: homage to the English mineralogist Dr. Normann F. M. Henry (1864-1932)[2,59].

55.Hessite Ag_2Te – Monoclinic System – Sulfide Class - (45.81% of Ag, and 54.19% of Te). Name: homage to the Swiss chemist G. H. Hesse (1802-1850)[2,60].

56.Heyrovskýite $(Pb,Ag)_5Bi_3S_8$ – Orthorhombic System – Sulfosalt Class - (2.84% of Ag, 27.48% of Bi, 54.50% of Pb and 18.50% of S). Name: homage to the Czech chemist J. Heyrovsky (1890-1967)[2,61].

57.Hocartite Ag_2FeSnS_4 – Tetragonal System – Sulfide Class - (41.60% of Ag, 10.77% of Fe, 22.89% of Sn, and 24.73% of S). Name: homage to the French mineralogist Raymind Hocart[2,3,62].

58.Iltisite HgSAg(Cl,Br) – Hexagonal System – Sulfide Class - (51.82% of Hg, 8.28% of S, 27.87% of Ag, 6.87% of Cl, and 5.16% of Br). Name: homage to the French mineral collector Antoine Iltis[2,63,64].

59.Imiterite Ag_2HgS_2 – Monoclinic System – Sulfide Class - (44.90% of Ag, 41.75% of Hg, and 13.35% of S). Name: reference from Imiter Mine (Morocco)[2].

60.Iodargyrite AgI – Hexagonal System – Iodide Class (45.95% of Ag, and 54.05% of I). Name: derivate of chemical composition: iodine + Greek (*argyros*) = silver[2,3,4,65,66,67].

61.Jalpaite Ag_3CuS_2 – Tetragonal System – Sulfide Class - (14.08% of Cu, 71.71% of Ag, and 14.21% of S). Name: reference to Jalpa Mine, Zacatecas (Mexico)[2,68].

62.Krennerite $(Au,Ag)Te_2$ – Orthorhombic System – Sulfide Class (56.44% of Te, 43.46% of Au, and traces of Ag). Name: homage to the Hungarian mineralogist Joseph A. Krenner (1839-1920)[2,4,60,69].

63.Kutínaite $Cu_{14}Ag_6As_7$ – Cubic System – Sulfide Class (43.85% of Cu, 31.02% of Ag, and 25.13% of As). Name: homage to the Czech mineralogist Jan Kutina[2,70,71].

64.Laffittite $AgHgAsS_3$ – Monoclinic System – Sulfosalt Class – (22.49% of Ag, 41.83% of Hg, 15.62% of S, and 20.06% of S). Name: homage to the French mineralogist Pierre Laffitti, Director of National School of Mines, Paris[2,72,73,74].

65.Laforêtite $AgInS_2$ – Tetragonal System – Sulfide Class – (40.03% of In, 37.61% of Ag, and 22.36% of S). Name: homage to the French metallographer Claude Laforêt[2,75,76].

66.Larosite $(Cu,Ag)_{21}(Pb,Bi)_2S_{13}$ – Orthorhombic System – Sulfosalt Class (53.51% of Cu, 9.56% of Ag, 9.26% of Bi, 9.18% of Pb, and 18.48% of S). Name: homage to the Canadian mineralogist Fred La Rose[2,77].

67.Lenaite $AgFeS_2$ – Tetragonal System – Sulfide Class; (24.51% of Fe, 47.34% of Ag, and 28.15% of S). Name: reference to Lena River (Russia)[2].

68.Lengenbachite $Pb_6(Ag,Cu)_2As_4S_{13}$ – Triclinic System – Sulfosalt Class – compare with cylindrite; (2.38% of Cu, 6.05% of Ag, 14.00% of As, 58.09% of Pb, and 19.48% of S). Name: reference from Lengenbach Quarry (Switzerland)[2,78].

69.Luanheite Ag_3Hg – Hexagonal System – Native Elements Class – (61.73% of Ag, and 38.27% of Hg). Name: reference to Luanhe River (People's Republic of China)[2,79].

70.Makovickyite $Ag_{1.5}Bi_{5.5}S_9$ – Monoclinic System – Sulfosalt Class – (10.11% of Ag, 71.85% of Bi, and 18.04% of S. Name: homage to the Danish mineralogist Prof. Dr. Emil Makovicky of University of Copenhagen[2].

71.Marrite $PbAgAsS_3$ – Monoclinic System – Sulfosalt Class – (22.19% of Ag, 15.41% of As, 42.62% of Pb, and 19.79% of S). Name: homage to the British geologist John Edward Marr (1857-1933)[2].

72.Matildite $AgBiS_2$ – Trigonal System – Sulfosalt Class – (28.31% of Ag, 54.85% of Bi, and 16.83% of S). Name: reference to the Matilda Mine (Peru)[2,16].

73.Mckinstryite $(Ag,Cu)_2S$ – Orthorhombic System – Sulfide Class – (23.94% of Cu, 60.96% of Ag, and 15.10% of S). Name: homage to the American economic geologist Hug Mckinstry (1896-1961)[2,80].

74.Miargyrite $AgSbS_2$ – Monoclinic System – Sulfosalt Class – (36.72% of Ag, 41.45% of Sb, and 21.83% of S). Name: comes from the Greek *meion* (minor) + *argyros* (silver) which means minor quatity of silver what the proustite, and pyrargyrite[2,16,17,44,81,82,83].

75.Miersite (Ag,Cu)I – Cubic System – Iodide Class – (7.10% of Cu, 36.17% of Ag, and 56.73% of I). Name: homage to the British mineralogist Henry Alexander Miers (1848-1942) of the Oxford University[2,67,84].

76.Moschellandsbergite Ag_2Hg_3 – Cubic System – Native Elements – (26.39% of Ag, and 73.61% of Hg). Name: reference from Moschellandsberg (Germany)[2,84].

77.Mummeite $Ag_2CuPbBi_6S_{13}$ – Monoclinic System - Sulfosalt Class – (2.81% of Cu, 14.29% of Ag, 55.36% of Bi, 9.15% of Pb, and 18.4% of S). Name: homage to the Australian mineralogist William G. Mumme[2].

78.Muthmannite (Ag,Au)Te – Monoclinic System (?) – Sulfide Class - (19.18% of Ag, 46.51% of Te, and 34.31% of Au); Name: homage to the German crystallographer and chemist Friedrich W. Muthmann (1861-1913)[2,4].

79.Naumannite Ag_2Se – Orthorhombic System – Sulfide Class – (73.21% of Ag, and 26.79% of Se); Name: homage to the German crystallographer and mineralogist Carl Friedrich Naumann (1797-1873)[2,85].

80.Neyite $Pb_7(Cu,Ag)_2Bi_6S_{17}$ – Monoclinic System – Sulfosalt Class – (2.88% of Cu, 1.63% of Ag, 41.04% of Bi, 37.88% of Pb, and 16.57% of S). Name: homage to the Canadian geologist Charles Stewart Ney (1918-1975)[2,86].

81.Novákite $(Cu,Ag)_{21}As_{10}$ – Monoclinic System – Sulfide Class - (55.58% of Cu, 9.93% of Ag, and 34.49% of As); Name: homage to the Czech mineralogist Jiri Novák (1902-1971)[2,87].

82.Ourayite $Ag_3Pb_4Bi_5S_{13}$ (?) – Orthorhombic System – Sulfosalt Class – (12.96% of Ag, 41.16% of Bi, 29.86% of Pb, and 16.02% of S); Name: reference to Ouray Mine (USA)[2,88,89,90].

83.Owyheeite $Ag_3Pb_{10}Sb_{11}S_{28}$ – Orthorhombic System – Sulfosalt Class – (6.24% of Ag, 12.09% of Bi, 21.14% of Sb, 41.97% of Pb, and 18.56% of S). Name: after its locality of Owyheei (USA)[2,91].

84.Paděraite $AgPb_2Cu_6Bi_{11}S_{22}$ – Monoclinic System – Sulfosalt Class – (9.76% of Cu, 2.76% of Ag, 58.53% of Pb, and 18.05% of S); Name: homage to the Czech mineralogist K. Padera[2].

85.Paraschachnerite $Ag_{1.2}Hg_{0.8}$ – Orthorhombic System – Native Elements Class - (44.65% of Ag, and 55.35% of Hg); Name: for its relationship to schachnerite[2,92].

86.Pavonite $AgBi_3S_5$ – Monoclinic System – Sulfosalt Class – (1.80% of Cu, 9.16% of Ag, 53.27% of Bi, 17.60% of Pb, and 18.16% of S). Name: homage to the Canadian mineralogist Martin Alfred Peacock (1898-1950)[2,93].

87.Pearceite $(Ag,Cu)_{16}As_2S_{11}$ - Monoclinic System – Sulfosalt Class – (77.45% of Ag, 6.72% of As, and 15.83% of S). Name: homage to the American chemist and metallurgist Richard Pearce (1837-1927)[2,14,24].

88.Penzhinite $(Ag,Cu)_4Au(S,Se)_4$ – Hexagonal System – Sulfide Class – (8.37% of Cu, 42.62% of Ag, 25.94% of Au, 10.40% of Se, and 12.67% of S); Name: reference to Penzhina River (Russia)[2,94].

89.Perroudite $Hg_5Ag_4S_5(Cl,I,Br)_4$ – Orthorhombic System – Halide Class – (22.78% of Ag, 52.94% of Hg, 6.77% of S, 10.72% of I, 3.80% of Br, and 2.99% of Cl); Name: homage to Pierre Perroud, Professor at Voltaire College, Geneva, Switzerland[2,95,96,97].

90.Petrovskaite $AuAg(S,Se)$ – Monoclinic System – Sulfide Class (31.80% of Ag, 58.06% of Au, 1.16% of Se, and 8.98% of S); Name: homage to the Russian mineralogist Nina Petrovskaya[2,7,98].

91.Petzite Ag_3AuTe_2 – Cubic System – Sulfide Class – (41.71% of Ag, 32.90% of Te, and 25.39% of Au); compare with fischesserite. Name: homage to the chemist W. Petz, discoverer of the mineral[2,4,60,99].

92.Pirquitasite Ag_2ZnSnS_4 – Tetragonal System – Sulfide Class – (12.38% of Zn, 40.85% of Ag, 22.48% of Sn, and 24.29% of S); forms a series with hocartite. Name: reference to the Pirquitas Mine (Argentina)[2,3,100].

93.Polybasite $(Ag,Cu)_{16}Sb_2S_{11}$ – Monoclinic System – Sulfosalt Class – (11.85% of Cu, 60.35% of Ag, 11.35% of Sb, and 16.45% of S); forms a series with pearceite; compare with antimonpearceite. Name: comes from the Greek *polys* (very) + *basis* (basis)[2,14,24].

94.Proustite Ag_3AsS_3 – Trigonal System – Sulfosalt Class – (65.41% of Ag, 15.14% of As, and 18.44% of S); forms a solid-solution with pyrargyrite; dimorphism with xanthoconite. Name: homage to the French chemist J. L. Proust (1755-1826)[2,4,6,101].

95.Pyrargyrite Ag_3SbS_3 – Trigonal System – Sulfosalt Class – (59.75% of Ag, 22.48% of Sb, and 17.76% of S); dimorphism with pyrostilpnite; forms a solid-solution with proustite. Name: pyrargyrite comes from the Greek *pyr* (fire) + *argyros* (silver)[2,4,6,45,101].

96.Pyrostilpnite Ag_3SbS_3 – Monoclinic System – Sulfosalt Class – (59.75% of Ag, 22.48% of Sb, and 17.76% of S); dimorphism with pyrargyrite. Name: comes from the Greek *pyr* (fire) + *stilpnos* (brilliant)[2,6,102].

97.Quadradite $Ag(Cd,Pb)(As,Sb)S_3$ – Tetragonal System – Sulfosalt Class – (21.91% of Cd, 26.29% of Ag, 18.26% of As, 10.10% of Pb, and 23.44% of S). Name: derived from the conspicuous quadratic shape of the mineral[2,103].

98.Ramdorhite $Ag_3Pb_6Sb_{11}S_{24}$ – Monoclinic System – Sulfosalt Class – (8.80% of Ag, 36.44% of Sb, 33.82% of Pb, and 20.94% of S); compare with andorite. Name: homage to the German mineralogist Paul Ramdohr[2,12,13].

99.Rayite$(Ag,Tl)_2Pb_8Sb_8S_{21}$ – Monoclinic System – Sulfosalt Class – (2.86% of Tl, 4.53% of Ag, 27.29% of Sb, 46.44% of Pb, and 18.87% of S); compare with semseyite. Name: homage to the Indian mineralogist Santosh K. Ray[2,104].

100.Roshchinite $Ag_{19}Pb_{10}Sb_{51}S_{96}$ - Orthorhombic System – Sulfosalt Class – (0.99% of Cu, 15.90% of Ag, 43.46% of Sb, 2.91% of As, 12.86% of Pb, and 23.89% of S). Name: homage to the Russian geologist Yuri Roschin (1934-1979)[2].

101.Samsonite $Ag_4MnSb_2S_6$ – Monoclinic System – Sulfosalt Class – (5.96% of Mn, 46.78% of Ag, 26.40% of Sb, and 20.86% of S). Name: reference from Samson Mine(USA)[2,105].

102.Schachnerite $Ag_{1.1}Hg_{0.9}$ – Hexagonal System – Native Elements Class – (39.66% of Ag, and 60.34% of Hg). Name: homage to the German mineralogist Doris Schachner (1904-1989)[2,106].

103.Schirmerite $Ag_3Pb_3Bi_9S_{18}$ to $Ag_3Pb_6Bi_7S_{18}$ – Orthorhombic System – Sulfosalt Class – (10.84% of Ag, 49.00% of Bi, 20.82% of Pb, and 19.33% of S); Name: homage to Former-superintendent J. H. L. Schirmer of the U. S. Mint, Denver, Colorado (USA)[2,82,89,90,107,108].

104.Selenostephanite $Ag_5Sb(Se,S)$ – Orthorhombic System – Selenide Class – (57.99% of Ag, 13.09% of Sb, 25.47%). Name: reference to the compositional similiraty to stephanite[2].

105.Sicherite $TlAg_2(As,Sb)_3S_6$ – Orthorhombic System – Sulfosalt Class – (23.27% of Tl, 24.56% of Ag, 11.09% of Sb, 19.19% of As, and 21.90% of S). Name: homage to the Swiss syndicalist Valentin Sicher[2,109].

106.Silver (Native silver) Ag – Cubic and Hexagonal Systems – Native Elements – forms a series with gold, the -3C, -2H and -4H polytypes are knowns[2,4,6,110,111].

107.Smithite $AgAsS_2$ – Monoclinic System – Sulfosalt Class – (43.69% of Ag, 30.34% of As, and 25.97% of S). Name: homage to the British crystallographer Herbert Smith (1872-1953)[2].

108.Sopcheite $Ag_4Pd_3Te_4$ – Orthorhombic System – Sulfide Class – (34.21% of Ag, 40.47% of Te, and 25.32% of Pd); Name: reference from Sopcha Massif(Russia)[2,112].

109.Stephanite Ag_5SbS_4 – Orthorhombic System – Sulfosalt Class – (68.33% of Ag, 15.42% of Sb, and 16.25% of S). Name: homage to the Austrian Archduke Victor Stephan (1817-1867) Former Mining Director[2,6,113].

110.Sternbergite $AgFe_2S_3$ – Orthorhombic System – Sulfide Class – (35.37% of Fe, 34.16% of Ag, and 30.47% of S). Name: homage to the Czech mineralogist Caspar Maria Sternberg[2,22,114,115].

111.Sterryite $Ag_2Pb_{10}(Sb,As)_{12}S_{29}$ – Orthorhombic System – Sulfosalt Class – (4.75% of Ag, 24.15% of Sb, 4.,95% of As, 45.66% of Pb, and 20.49% of S). Name: homage to the Canadian mineralogist T. Sterry Hunt (1826-1892)[2,116].

112.Stetefeldtite $Ag_2Sb_2O_5(OH)_2$ - Cubic System – Oxide Class – (37.73% of Ag, 42.59% of Sb, 0.09% of H, and 19.59% of O). Name: homage to the German-American mining engineer Carls Stetefeldt (1838-1896)[2].

113.Stromeyerite AgCuS – Orthorhombic System – Sulfide Class - (31.23% of Cu, 53.01% of Ag, and 15.76% of S); Name: homage to the German mineralogist and chemist Friedrich Stromeyer[2].

114.Stützite $Ag_{5-x}Te_3$ – Hexagonal System – Sulfide Class - (56.98% of Ag, and 43.02% of Te). Name: homage to the Austrian mineralogist Andreas Stutz (1747-1806)[2,47,48,49].

115.Sylvanite $AuAgTe_4$ – Monoclinic System – Sulfide Class – (6.27% of Ag, 59.36% of Te, and 34.36% of Au). Name: comes from the Latim *silvanium* which means tellurium and Transylvania (Romania)[2,4,60].

116.Telargpalite $(Pd,Ag)_3Te$ (?) – Cubic System – Sulfide Class – (4.82% of Ag, 28.54% of Te, and 66.64% of Pd). Name: for the composition (Te, Ag and Pd)[2,117].

117.Tillmannsite $(Ag_3Hg)(V,As)O_4$ – Tetragonal System – Oxide Class – (0.17% of V, 1.60% of Ag, 97.77% of Hg, 0.13% of As, and 0.33% of O). Name: homage to the Austrian mineralogist Ekkhart Tillsmanns[2,118].

118.Toyohaite $Ag_2FeSn_3S_8$ – Tetragonal System – Sulfide Class – (6.32% of Fe, 24.40% of Ag, 40.28% of Sn, and 29.01% of S). Name: reference from Toyo Mine (Japan)[2].

119.Treasurite $Ag_7Pb_6Bi_{15}S_{32}$ – Monoclinic System - Sulfosalt Class – (12.26% of Ag, 50.90% of Bi, 20.18% of Pb, and 16.66% of S). Name: reference from Treasure Mine (USA)[2,107,108].

120.Trechmannite $AgAsS_2$ – Trigonal System – Sulfosalt Class – (43.69% of Ag, 30.34% of As, and 25.97% of S). Name: homage to the English mineralogist Charles Trechmenn (1851-1917)[2].

121.Tsnigriite $Ag_9SbTe_3(S,Se)_3$ – Monoclinic System – Sulfosalt Class – (60.87% of Ag, 7.63% of Sb, 24.00% of Te, 2.48% of Se, and 5.03% of S). Name: from the initials of the Russian denomination for the Central Scientific-Research Institute of Geological Prospecting in Moscow[2].

122.Uchucchacuaite $AgPb_3MnSb_5S_{12}$ – Orthorhombic System – Sulfosalt Class – (3.09% of Mn, 6.07% of Ag, 34.24% of Sb, 34.96% of Pb, and 21.64% of S). Name: reference from Uchuc-Chacuaia Region (Peru)[2,12,119].

123.Uytenbogaardtite Ag_3AuS_2 – Tetragonal System – Sulfide Class – (55.35% of Ag, 33.69% of Au and, 10.97% of S). Name: homage to the Dutch mineralogist Willem Uytenbogaardt (1818-?)[2,4,6].

124.Vikingite $Ag_5Pb_8Bi_{13}S_{30}$ – Monoclinic System – Sulfosalt Class – (9.18% of Ag, 46.24% of Bi, 28.21% of Pb, and 16.37% of S). Name: reference to the Vikings[2,108,109].

125.Volynskite $AgBiTe_2$ – Hexagonal System – Sulfosalt Class – (2.86% of Ag, 35.53% of Bi, and 44.61% of Te). Name: homage to the Polish economic geologist mineralogist I. S. Volynskii (1900-1947)[2].

126.Wallisite $PbTl(Cu,Ag)As_2S_5$ – Triclinic System – Sulfosalt Class – (25.66% of Tl, 5.98% of Cu, 3.39% of Ag, 18.82% of As, 26.02% of Pb and 20.13% of S). Name: was proposed in reference to Wallis (Switzerland)[2,120].

127.Weishanite$(Au,Ag)_{1.2}Hg_{0.8}$ – Hexagonal System – Native Elements Class – (8.74%

of Ag, 43.36% of Hg, and 47.90% of Au). Name: reference from Weihan Province (People's Republic of China)[2].

128.Xanthoconite Ag_3AsS_3 – Monoclinic System – Sulfosalt Class – (65.41% of Ag, 15.14% of As, and 19.44% of S). Name: comes from the Greek *xanthos* which means yellow, and *khroa*, which means color[2].

129.Zoubekite $AgPb_4Sb_4S_{10}$ – Orthorhombic System – Sulfosalt Class (6.18% of Ag, 27.92% of Sb, 47.51% of Pb, and 18.38% of S). Name: homage to the Czech geologist Vladimir Zoubek[2].

CONCLUSIONS

The relatively small number of silver minerals (129 species described and validated by IMA – International Mineralogical Association) is related to the low chemical reactivity of the chemical element. Only the pyrargyrite, the silver (native silver), the tetrahedrite, the tennantite and the acanthite are industrial sources of the metal, that also can be obtained as a subproduct of the copper, lead and zinc sulfides.

The majority of silver minerals are Sulfosalts and sulfides, originated by hydrothermal process in ore veins.

The main silver producers on a global scale are: Mexico and Canada; but the countries with major bulk reserves are: Canada, Mexico, USA, Australia, and Peru[121]. Brazil does not present important argentiferous deposits, a few silver deposits occurring in restricted regions of the Minas Gerais, São Paulo, Paraná, Bahia, and Goiás states. Silver, as subproduct can be obtained from lead, zinc and copper mines in São Paulo, Paraná, Santa Catarina, Bahia, and Rio Grande do Sul (Santa Maria mine, Minas do Camaquã, Caçapava do Sul) states.

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