BRAZILIANITE MINERALIZATION – THERMODYNAMIC CONTROL, ORIENTAL PEGMATITE PROVINCE, MINAS GERAIS, BRAZIL

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The rarity and beauty of the semi-precious, lettuce green, hyaline and perfect crystal form Brazilianite ($NaAl_3(PO_4)_2(OH)_4$ in the Oriental Pegmatite Province (Paiva, 1946), particularly in pegmatites at Galiléia, Governador Valadares, Minas Gerais, attract the attention of the scientific world as well as the gemology sectors. In an area of about 10 km^2 involving several mining works and “garimpos”, beryl, aquamarine, chrysoberyl, tourmaline, morganite, and feldspar and kaolinite for ceramic industry have been recovered together with rare minerals for collect purposes. Mesoscopic examination of the occurring minerals interesting brazilianite (Pough & Henderson, 1945; Godoy, 1945) detailed in about 12 pegmatites from a total of 35 studied (Pires et al., 2005), previously studied (Correia Neves et al., 1986) revealed the presence, besides the more abundant species, a group of phosphates, such as gormanite ($Fe^{2+}{}_3Al_4(PO_4)_4(OH)_4.2H_2O$), lazulite ($MgAl_2(PO_4)_2(OH)_2$), herderite ($CaBe(PO_4)(OH)$, hurlbutite ($CaBe_2PO_4$), hureaulite ($Mn_5(PO_4)_3(OH)_2.4H_2O$), moraesite ($Be_2(PO_4)(OH).4H_2O$) and silicate minerals such bertrandite ($Be_4Si_2O_7(OH)_2$, euclase ($AlBeSiO_4(OH)$, beryl ($Be_3Al_2Si_6O_{18}$), morganite, phenakite ($BeSiO_4$), quartz and magnetite. Brazilianite had its crystallographic parameters defined (Tavora, 1945). Muscovite appears in all pegmatites apparently coexisting with all phases was formed in at least three stages. Spodumene, petalite, lepidolite, amblygonite and triphylite are the Li-minerals also occurring but in very subordinate amount, but important at CBL-pegmatites. Spatial relation between the minor occurring minerals with tourmaline, biotite, muscovite, beryl and almandine happened sparsely and considered in single chemical potential diagrams in terms of μH_2O-μH^+ in order to establish the thermodynamic equilibrium conditions. The intimate coexistence of the minerals in close mesoscopic relationship with each another defined as paragenesis, performed in the pegmatite field of Galiléia allowed to prepare the mineral reactions aiming the brazilianite formation. Combination of isolate mineral coexistences permitted to elaborate the unique and solitary chemical potential diagram. Brazilianite forms with Q+H_2O in practically all reactions and the H^+/H_2O ratio decreases in the sequence of reactions starting in lazulite, garnet, herderite, muscovite, bertrandite, tourmaline, biotite and gormanite:

$MgAl_2(PO_4)_2(OH)_2 + 2NaAlSi_3O_8 + 2H^+ = NaAl_3(PO_4)_2(OH)_4 + 3SiO_2$ **2/0** (lazulite) (albite) (brazilianite) (quartz)

$2Fe_3Al_2Si_3O_{12} + 5NaAlSi_3O_8 + 2Ca_5(PO_4)_3F + 16H^+ = 3NaAl_3(PO_4)_2(OH)_4 + 2Fe_3O_4 + 21SiO_2 + 2H_2O$ (**8.0**) (garnet) (albite) (brazilianite) (magnetite) (quartz)

$2CaBe(PO_4)F + 3NaAlSi_3O_8 + 8H^+ = NaAl_3(PO_4)_2(OH)_4 + 9SiO_2 + 2H_2O$ (**4.0**) (herderite) (albite) (brazilianite) (quartz)

$KAl_3Si_3O_{10}(OH)_2 + 2Ca_5(PO_4)_3F + 6NaAlSi_3O_8 + 22H^+ = 3(NaAl_3(PO_4)_2(OH)_4 + 21SiO_2 + 6H_2O$ (**3.67**) (muscovite) (apatite) (albite) (brazilianite) (quartz)

$2Be_4Si_2O_7(OH)_2 + 2Ca_5(PO_4)_3F + 9NaAlSi_3O_8 + 32H^+ = 3(NaAl_3(PO_4)_2(OH)_4 + 29SiO_2 + 11H_2O$ (**2.91**) (bertrandite) (apatite) (albite) (brazilianite) (quartz)

$3NaFe_3Al_6(BO_3)_3Si_6O_{18}(OH,F)_4 + 4Ca_5(PO_4)_3F + 102H^+ = 6(NaAl_3(PO_4)_2(OH)_4 + 18SiO_2 + 45H_2O$ (**2.27**) (tourmaline) (brazilianite) (quartz)

$9KFe_3AlSi_3O_{10}(OH)_2 + 2Ca_5(PO_4)_3F + 90H^+ = 3(NaAl_3(PO_4)_2(OH)_4 + 9Fe_3O_4 + 27SiO_2 + 48H_2O$ (**1.875**) (biotite) (apatite) (brazilianite) (magnetite) (quartz)

$Fe_3Al_4(PO_4)_4(OH)_6.2H_2O + Al_2SiO_5 + 4H^+ = 2(NaAl_3(PO_4)_2(OH)_4 + 3FeS_2 + SiO_2 + 3\ H_2O$ **(1.33)** (gormanite) (kyanite) (brazilianite) (pyrite)(quartz)

The diagram shows clearly the natural dependence of the brazilianite crystallization on the participation of Al-rich minerals together with PO_4, along with μH_2O and μH^+. Invariant reactions among the brazilianite-participant phases are also in equilibrium with the slopes approximately following the main trend of the principal set of reactions. The slope of the invariant associations ($\mu H^+/\mu H_2O$ ratios) varied from 2/0 (zero), 8.0, 4.0, 3.67, 2.91, 2.27, 1.875 and 1.33 for brazilianite-producing reactions, respectively for lazulite, muscovite, bertrandite, tourmaline, herderite, gormanite, garnet and biotite.

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