Conditions for hydrothermal cobalt and nickel mineralization – suggestions from some little known, historical ore deposits in Italy

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We present ongoing research about three poorly known, historical Ni-Co-bearing hydrothermal deposits in different geological contexts: the Ni-Co-As-Sb-Au-bearing Arburese vein system (SW Sardinia), the Co-As-rich Usseglio vein system (Piedmont) and the small Cu-Ag-Co-Ni-Pb-Te-Se stockwork ore at Piazza (eastern Liguria). These deposits share some similarities to the Five Element Vein-type, Co-Ni-Ag-Bi-As ores but only the first two display km-sized development and were economic for Co and Ni. The Arburese Ni-rich veins occur in Paleozoic basement near two Variscan plutons. The Co-rich Usseglio and Piazza deposits share ophiolitic contexts: the Usseglio veins crosscut metabasalts near the Lanzo peridotite massif, while the Piazza stockwork crosscuts low-grade metamorphic gabbro of the Bracco ophiolite massif. The Arburese and Usseglio deposits share a complex mineral assemblage with early Bi-bearing Ni-Co arsenides-sulfarsenides followed by Ag-base metal sulfides, in siderite-quartz-baryte gangue. The Piazza deposit stands apart with its early Ag-Pb-Bi telluride-selenide stage with Co-Ni sulfides plus bornite replaced by chalcopyrite, in prehnite-albite-chlorite gangue. Piazza shares its Se-rich character with the Arburese veins, which host Se in base metal sulfides. Preliminary geothermometric estimates are provided by fluid inclusion analyses (Usseglio and Arburese) and chlorite composition (Piazza). Co-Ni arsenide precipitatation occurred at ≈200°C (0.5 kbar) after a vigorous boiling episode depositing baryte, while later base metal sulfide deposition occurred at 80÷140°C. Ore fluids are NaCl-$CaCl_2$-bearing brines (18÷25 equiv. mass% NaCl). Ore carbonates display stable isotope signatures compatible with such low temperature brines, typical for five element vein-type deposits. Vein-related chlorites at Piazza provide higher temperatures for ore deposition in the range of 200÷280°C (avg 230°C), and the carbonate-free prehnite-feldspar assemblage is compatible with CO_2-degassed, alkali chloride waters. No data are available on hydrocarbons in the ore fluids, although observed enrichments in Se and negative $\delta^{13}C$ in carbonates suggest interaction with carbonaceous shales. In their own regional metallogenic contexts the three deposits stand out and open questions about source rocks and controls on Co/Ni: e.g., within the highly mineralized, Ni-free southern Sardinian crust the Arburese Ni-Co-As vein system is unique, as is the Usseglio Co-As vein system within the western Alps rich in ophiolites and post-peak hydrothermal deposits. The northern Apenninic ophiolites, hosting the unique Cu-Ag-Co-Ni-Pb-Te-Se Piazza deposit, may actually have the greatest potential for hydrothermal Co-Ni mineralization as their many oceanic exhalative Cu-Fe deposits are highly anomalous in Co. Piazza ore fluids recycled metals of various provenance, like Co and Ag, but no economic ore was formed. Could the missing arsenic and carbonate components be part of the problem?