



QUADRILÁTERO FERRÍFERO FIELD TRIP 24-25 October 2013

INTRODUCTION

The aim of Quadrilátero Ferrífero (QF) ("Iron Quadrangle") field trip is to examine the geological setting and mineral deposits of this world-class mineral province. Located in the southern edge of the São Francisco craton, the QF region is delimited by four almost mutually perpendicular ridges underlain by Paleoproterozoic banded iron formation and quartzites (hence the name "Iron Quadrangle"). The Precambrian section exposed in the QF consists of four major lithostratigraphic units: (1) Archean gneisses, migmatites, and granitoids, including TTG suites and high-K granites; (2) the Archean Rio das Velhas Supergroup, made up of komatiites, pillow basalts flows, low-to medium-grade Fe and Mn exhalative cherts, as well as clastic and volcanoclastic rocks; (3) the Paleoproterozoic Minas Supergroup, which comprises passive margin to syn-orogenic sedimentary assemblages, including a Lake Superior type banded iron formations (4) the Itacolomi Group, composed of sandstones and conglomerates. The QF mining district is the most important gold and iron producer in Brazil. (Alkimin and Noce, 2006).

Historical production and present gold reserves exceed 1.000 t. The QF iron ore resources reach 15 Gt at > 64 wt.% Fe. The high grade soft hematite deposits, averaging > 66% wt Fe, were formed mainly by supergene leaching of itabirite, i.e., metamorphosed BIF with ca. 35 % wt Fe. In 2011 the QF produced 367 MT ROM of iron.

PROGRAM

Day 01 – All participants will visit the Casa de Pedra iron mine. It will be given an overview of the main attributes and generation process of various categories of BIF-related iron ores in the Ferriferous Quadrangle.

Day 02 – The participant should decide for one of the following options: **Group 1**, up to 15 people will visit the underground Cuiabá gold mine; **Group 2**, up to 20 people will visit the underground Passagem de Mariana gold mine and examine several outcrops in the region around the historical town of Ouro Preto; and **Group 3**, up to 20 people will visit key outcrops of komatiites of the Quebra Ossos Group and participate on a discussion of the volcanology and Ni-Cu sulfide mineralization associated with komatiites.

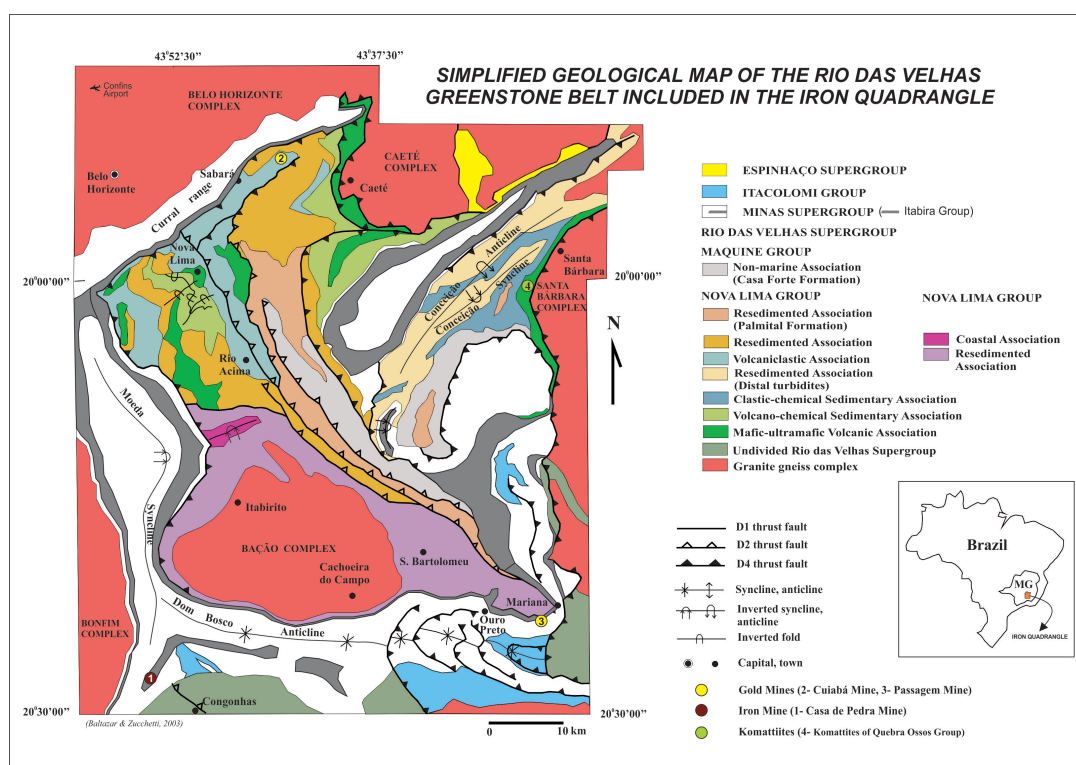


Fig. 1 Iron Quadrangle Map

RIBEIRO-RODRIGUES, L. C. OLIVEIRA, C. G. de; FRIEDRICH, G. The Archean BIF-hosted Cuiabá Gold deposit, Quadrilátero Ferrífero, Minas Gerais, Brazil. **Ore Geology Reviews**, v. 32, n. 3-4, p. 543–570, Nov. 2007.

VIAL, D. S.; DUARTE, B.P.; FUZIKAWA K.; VIEIRA, M.B.H. An epigenetic origin for the Passagem de Mariana gold deposit, Quadrilátero Ferrífero, Minas Gerais, Brazil. **Ore Geology Reviews**, v. 32, n. 3-4, p. 596–613, Nov. 2007.

ALKMIN, F.F.; NOCE, C. M. Outline of the Geology of the Quadrilátero Ferrífero. In: Alkmim, F.F. and Noce, C.M. (Ed.) **The Paleoproterozoic Record of the São Francisco Craton**. IGCP 509 Field workshop, Bahia and Minas Gerais, Brazil, p: 37-58, Set. 2006.

DAY ONE: THURSDAY 24 OCTOBER

Casa de Pedra Iron Mine

Background Geology: Henrile Pinheiro Meireles - CSN

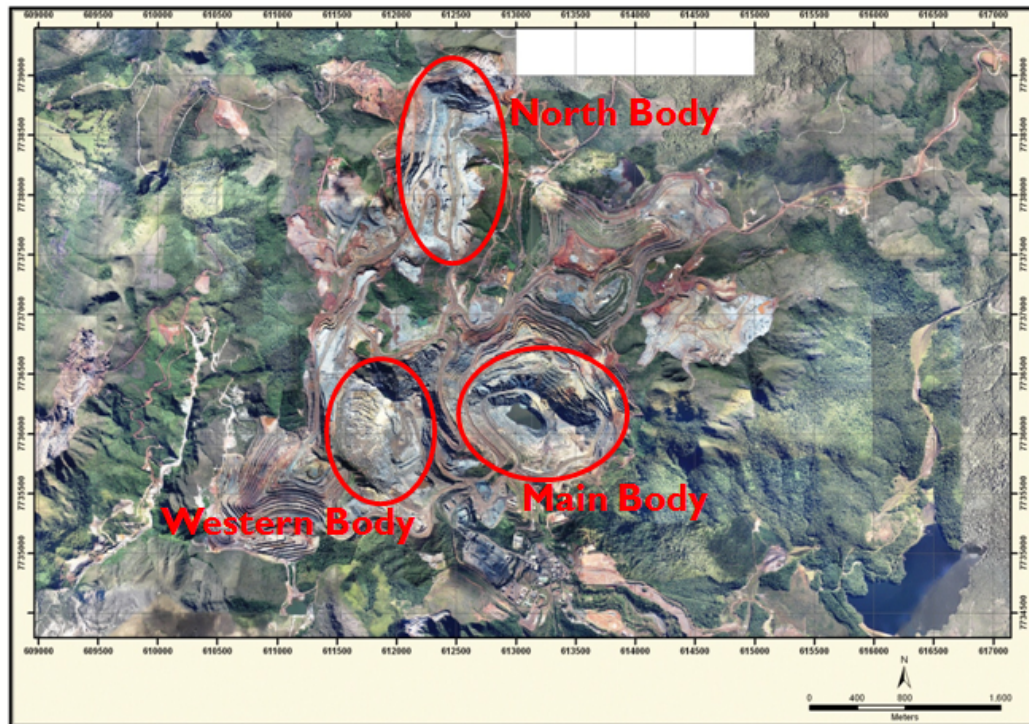


Fig. 2 Google Image of Casa de Pedra Mine

The Casa de Pedra Mine is located in the southwestern portion of the Iron Quadrangle (Fig 1). Rocks of the Rio das Velhas and Minas Supergroups occur in the area, located in a region of great structural complexity, at the intersection of two of the major synclines of the Iron Quadrangle: the Dom Bosco Syncline (E-W orientation) and the Moeda Syncline (N-S orientation), both cut by thrust faults and transcurrent faults (e.g. Engenho Fault). The mine is divided into three supergenic ore bodies, denominated Main Body, Western Body and North Body (Fig. 2), all hosted in the Cauê Formation of the Minas Supergroup, of Paleoproterozoic age.

The Cauê Formation consists of classic (siliceous) itabirites, amphibolitic itabirites, carbonatic itabirites, manganiferous itabirites and high grade hematitic ore bodies (Fig. 3). Content of iron in these high grade ores are around 64% and they consist of 75% hematite, 10% martite and 2% magnetite. The itabiritic ores show iron concentrations below 64%, and consist of 30% hematite, 18% martite, 4% magnetite, 16% goethite and 32% quartz.

The Main Body consists mainly of granular hematite and magnetite, and show a relation of obliquity between bedding (S0) and schistosity (S2), while the other bodies show a relation of parallelism between these two structural features. The textural and mineralogic features resulting from deformation processes and recrystallization are crucial in defining the different types of ore and their metallurgical processes.

DAY TWO: FRIDAY 25 OCTOBER

GROUP 1: Cuiabá Gold Mine

Background Geology: Rodrigo R.C. Fernandes. Anglo Gold Ashanti - AGA

Casa de Pedra Iron mine is located in the southwest portion of the Quadrilátero Ferrífero.



Fig. 3 Cuiabá-Banded Iron Formation (BIF)

The Cuiabá Gold Deposit is located in the northern part of the Quadrilátero Ferrífero, Minas Gerais State, Brazil. The region constitutes an Archean granite–greenstone terrane. The stratigraphy of the Cuiabá area is part of the Nova Lima Group, which forms the lower part of the Rio das Velhas Supergroup. The lithological succession of the mine area comprises, from bottom to top, lower mafic metavolcanics intercalated with carbonaceous metasedimentary rocks, the gold-bearing Cuiabá-Banded Iron Formation (BIF), upper mafic metavolcanics and volcanoclastics and metasedimentary rocks. Tectonic structures of the deposit area are genetically related to deformation phases D1, D2, D3, which took place under crustal compression representing one progressive deformational event (En). The bulk of the economic-grade gold mineralization is related to six main ore shoots, contained within the Cuiabá BIF horizon, which range in thickness between 1 and 6 m. The BIF-hosted gold

orebodies (>4 ppm Au) represent sulfide-rich segments of the Cuiabá BIF, which grade laterally into non-economic mineralized or barren iron formation. The gold is fine grained (up to 60 μm), and is generally associated with sulfide layers, occurring as inclusions, in fractures or along grain boundaries of pyrite, the predominant sulfide mineral (>90 vol.%). Gold is characterized by an average fineness of 0.840 and a large range of fineness (0.759 to 0.941). The country rocks to the mineralized BIF show strong sericite, carbonate and chlorite alteration, typical of greenschist facies metamorphic conditions.

The mineralized Cuiabá BIF is the result of sulfidation involving pervasive replacement of Fe-carbonates (siderite–ankerite) by Fe-sulfides. Gold mineralization at Cuiabá shows various features reported for Archean gold–Iode deposits including the: (1) association of gold mineralization with Fe-rich host rocks; (2) strong structural control of the gold orebodies, showing remarkable down-plunge continuity (>3 km) relative to strike length and width (up to 20 m); (3) epigenetic nature of the mineralization, with sulfidation as the major wall–rock alteration and directly associated with gold deposition; (4) geochemical signature, with mineralization showing consistent metal associations (Au–Ag–As–Sb and low base metal), which is compatible with metamorphic fluids (Rodrigues et. al. 2007)

GROUP 2: Passagem Gold Mine and the geologic scenario of the Quadrilátero Ferrífero

Background Geology: Fernando F. Alkmim. Universidade Federal de Ouro Preto - UFOP



Fig. 4 BIF (itabirite) of the Paleoproterozoic Cauê Formation, showing the effects of the supegene enrichment. (Serra Azul Mine, northwestern QF).

The Passagem de Mariana gold mine is located in the southeastern part of the QF, at ca. 7 km east of the town of Ouro Preto. The gold deposit, characterized by structurally-hosted lode–gold vein system, involves by complex tectonic interlayering of upper-greenschist to lower- amphibolite schists, phyllites, quartzites, dolomites and banded iron formation of the lower portion of the Paleoproterozoic Minas Supergroup. The mine produced more than 60 metric tonnes of gold, from the end of the 17th Century until 1954. The mineralization is confined to a bedding-parallel shear zone located between the lower portion of Paleoproterozoic Cauê Iron Formation and upper portion the Archean Nova Lima Group. This shear zone extends for tens km farther east of the Passagem mine and hosts numerous small gold deposits. Passagem de Mariana ore bodies are veins composed of white quartz (> 60 vol.%), carbonate (ankerite),

tourmaline (10 vol %), sericite, arsenopyrite, pyrite and pyrrhotite. Minor amounts of chalcopyrite, galena, löllingite, berthierite, and maldonite are present throughout the deposit. Gold occurs mostly as very fine particles, as inclusions, and along fractures in arsenopyrite grains. Gold abundance is directly proportional to sulfide concentration. The veins crosscut the main foliation at low angles in all lithologic units except the itabirite. The richest ore bodies occur in association with a itabiritic hanging wall. Passagem de Mariana gold deposit is considered epigenetic.

Passagem gold mineralization appears to have resulted from the circulation of CO₂-rich and low-salinity hydrothermal fluids (>250 °C), along a structurally controlled path (bedding parallel shear zone) at the end of the main deformation phase and metamorphic peak, during Transamazonian event (2.124 and 2.04 Ga). The mine is 409 m deep and is flooded below the 315 level (83m below surface). Access is via inclined shafts, 1400 m in length and dipping 15°, generally in an easterly direction (Vial et al. 2007).

The geologic scenario of the QF will be depicted during examination of a cross-section in the surroundings of Ouro Preto. Starting in Itacolomi Natural Park, the field trip will examine the Archean and Paleoproterozoic lithostratigraphic units, as well as the main fabric elements that characterize the geological architecture of the QF.

GROUP 3. Komattites of Quebra Ossos Group

Background Geology: César Ferreira Filho. Universidade de Brasília – UNB

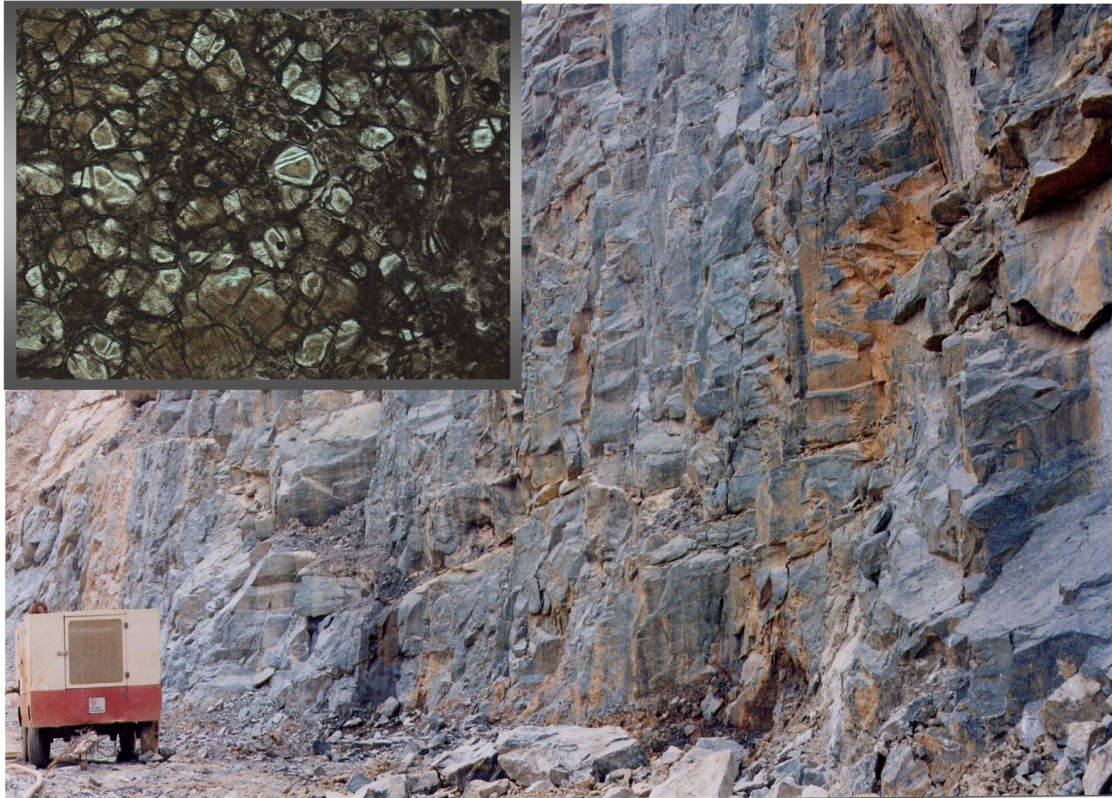


Fig.5 Massive dunite with adcumulate texture. Channelized komatiitic flow.

Komatiites of the Quebra Osso Group form the lower portion of the Archean Rio das Velhas greenstone belt. Komatiitic rocks are exposed in a NNE trending belt located to the west of town of Santa Bárbara and Catas Altas. This belt consists mainly of metamorphosed ultramafic rocks with tectonic fabric, including chlorite-talc schist and serpentinite, but rocks with primary textures are preserved within the wider portion of the belt. Geological mapping and petrographic studies developed in this portion of the Quebra Ossos Group, indicate that the komatiitic volcanic field consisted of robust channelized flows (lava pathway), which are characterized by dunite with adcumulate to mesocumulate texture. These olivine cumulate rocks have high MgO content (up to 40 wt. %) and low Al_2O_3 contents (< 5 wt. %). Channelized flows are associated with undifferentiated sheet flows and breccia flows, interpreted as marginal facies of the lava pathway, as well as banded iron formations.