



The Archean-Paleoproterozoic structural evolution of the Caraíba Cu-Deposit, northern São Francisco Craton, Brazil: A historical review of its understanding coevally with the development of a high-risk mining project

Luiz Jose Homem D'el-Rey Silva^{1*} , André Menezes Saboia² 

¹University of Brasília, Brazil, Instituto de Geociências, IG-UnB, Campus Darcy Ribeiro, Brasília, Distrito Federal, Brazil, CEP: 70.910-900.

²Geological Survey of Brazil, Setor Bancário Norte - SBN, Quadra 02, Asa Norte, BLoco H - Edifício Central Brasília, 1º andar, sala 101. Brasília - DF - Brazil, CEP: 70040-904.

Appendix 1

Information numbered A1-1 to A1-26 in the main text.

(A1-1) December 1977 to October 1983: Manager of the Mine Geology Division; Oct1983-Dec1984: Mine Operation Superintendent; Jan1985-Jan1989: Mining Planning Superintendent and Manager of the Exploration Geology Division; 1989-2000: independent consultant eventually hired by the Caraíba Mineração Company; and 2007- 2010: years of his two last scientific publications on the geology of the Caraíba Mine and Curaçá River Valley Terrane. <https://www.researchgate.net/publication/280681639>

(A1-2) Geologists Adelmo Rodrigues da Silva (senior adviser for the Directory) and Pêrsio Mandetta (Manager of the Exploration Geology Division) worked at Salvador. Still, they never lost an opportunity to invite specialists to visit the Mine. Due to their endeavours, Prof. A. Naldret, an international authority on Nickel sulphide deposits worldwide, visited the open pit in the early days of operation at Caraíba (1978). Seated beside the corresponding author on the edge of the upper bench of the open pit, both considering the uncertainties about the orebody's geology, Prof. Naldret openly declared astonishment with the size of the industrial complex at Caraíba and its buildings in concrete. Adelmo and Pêrsio also hired experts on structural geology and tectonics as consultants for Caraíba at different opportunities. Among these, Prof. Gabor Gáal, a famous Hungarian-Finnish professor, also became a leader (1982-1983) in the post-graduation course in Geology at the Federal University of Bahia (UFBA) and supervisor in the MSc studies (1982-1984) carried out by the corresponding author. Prof. Yociteru Hasui (IPT-São Paulo) trained the team of CMSA's geologists in 1980-1982. He gave a short course on modern structural analysis comprising a first week of classes at Caraíba and a second week of fieldwork exercises performed along the profile Pinhões-Poço de Fora (see Hasui et al., 1982). Professor Emanuel Jardim de Sá (UFRN-Brazil) received from CMSA the necessary support for performing

detailed structural analysis and training students in the Curaçá River Valley (1982), and remained hired as an eventual consultant up to 1988. Y. Hasui and E. Jardim de Sá are among the best structural geologists ever known in Brazil.

(A1-3) The increasing demand for base metals pushed geologists in a rush for mapping the vast territory of the country.

(A1-4) The village of Pilar, situated 14 km West of the Caraíba Mine, was built between 1977 and 1979 and reached a population over 5,000 inhabitants in 1983-1984.

(A1-5) The water supply to the population living in the older villages around Caraíba and Pilar could only be possible because the Caraíba Mining Company remained in charge of all costs and technical aspects related to the operation of the pipeline since the station for capturing water in the São Francisco River until the water pumping up to Caraíba. Although the Bahia State Government could not afford to build and assume the operation and maintenance of the enormous pipeline, local politicians took advantage of the official propaganda emphasizing the benefits for several local populations at that time.

(A1-6) As the Manager of the Mine Geology Division, the corresponding author was one the central pieces in meetings concerning the study of alternatives to guarantee the future of the mineral exploration in the Curaçá River Valley after the ore reserves at Caraíba have finished, mainly because of the survival of the industrial plant constructed at Caraíba and the village of Pilar. In two of these meetings (the early 1980s, held in Petrolina), the importance of the Caraíba Mine was emphasized for the viability of a new airport at Petrolina to directors of the two leading civil aviation companies in Brazil at that time (VARIG and VASP).

(A1-7) Ore grade means the percentual of the chemical element constitutive of the ore (for example: Fe, Mn, Al, Cu, Au). In iron deposits the ore normally contains 50%-70% Fe, whereas in most copper deposits the ore grade commonly varies around 1% Cu or less, and very rarely reaches 8%-10% Cu.

(A1-8) DOCEGEO was the subsidiary of CVRD (another state company, lately privatized and simply renamed as VALE) in charge to prospect non-ferrous minerals across the country.

(A1-9) The pioneers at Caraíba used the English language of varied quality for communicating with the foreigners, which were normally from Canada, Finland, and Greece.

(A1-10) Adelmo, Pêrsio, and Luiz D'el-Rey.

(A1-11) Geologists Zara G. Lindenmayer and João Batista G. Teixeira.

(A1-12) The CMSA staff of geologists was divided into two Divisions, which lasted from Dec/1977 until the end of 1989. In 1990, the Regional Exploration Division was managed by Pêrsio Mandetta, who led the group comprising geologists Eduardo Paixão de Sá, José Acúrcio C. de Moraes, Mário C. Reinhardt, Nilton D. Franke, Paulo Roberto S. de Carvalho, Paulo Henrique L. Varela, and Marcelo Gonçalves, altogether responsible for searching other mineral deposits in the Curaçá River Valley and elsewhere in the whole country, particularly in Northeastern Brazil. The team in the Mine Geology Division, led by Luiz D'el-Rey, included geologists José Genário de Oliveira, Wilson Miola, Francisco José de Lima e Silva, Alexandre Magno Rocha da Rocha and, lately, Paulo Cavalcante. Geologists Ernesto Barreto, Virdálio Senna Filho, Washington de Jesus Sant'Anna da Franca Rocha and Hailton Melo lasted for a shorter time in position in the Mine Geology Division. Geologists Nilton Franke and Paulo R.S. Carvalho started working in DOCEGEO and participated actively in the early study of the orebody (DOCEGEO, 1977-1978).

(A1-13) Administrative personnel worked under severe pressure to speed up the importation of spare parts. Working in the central office at Rio de Janeiro, the technician Ramon V. dos Santos overcame the official bureaucracy during the 1970s and 1980s and contributed to the success of Caraíba.

(A1-14) Geologists are the backbone of a Mining Company and are responsible for answering three fundamental questions: Where is the ore?; How much ore do we have?; and What is the most profitable way to exploit the ore?. As the Manager of the Mine Geology Division at Caraíba, it was the duty of the corresponding author to ensure that the geological model was not just a theoretical exercise, but a practical tool that could accurately represent the entire orebody in space and in a sequence of coherent vertical cross-sections. This was crucial for the prompt presentation of answers to these fundamental questions.

(A1-15) The corresponding author first presented a cross-section displaying the pioneer fold interpretation of the Caraíba orebody to the international scientific community visiting the mine during a field excursion part of the International Symposium on Archean-Proterozoic Evolution (ISAP), held at Salvador in September 1982.

(A1-16) Until the completion of Luiz Del-Rey's MSc Dissertation, every new field example of the interference of two folds affecting the metamorphic banding S1 was a matter of special meetings and warm discussions involving almost all of the CMSA's geologists as these had gained a crescent enthusiasm about the geology of high-grade terranes, after

the training received in the field with Profs. Y. Hasui, E. Gabor Gáal, and E. Jardim de Sá. Thus, discovering any outcrop with new exciting features (generally folds) was always an opportunity for Pêrsio Mandetta and his team of younger geologists to travel over 500 km from Salvador to meet the whole team of Mine geologists directly in the outcrop. The warm discussions (hot, sometimes) never ended despite always being fruitful. Moreover, after each meeting, each geologist followed the path to meet their own duties in the Copper Project, leaving to the corresponding author the responsibility to keep working on the 3-D interpretation of the poly-folded orebody and slicing it into vertical and horizontal sections fundamental for computing ore reserves and for providing the critical information required for any decision relative to the open pit and underground mine's planning.

(A1-17) Mining engineers were also under intense pressure during the first years at Caraíba, and, at a particular moment, the Manager of the Open Pit Mine, Vitor Retamal, a well-trained Chilean engineer recently hired by Caraíba at that time, mistook the operations necessary for controlling the Cu-content in the run-off-mine material as spoil for the achievement of the level of production in terms of tons of ore per month. He attempted to keep control of such operations but could not remove the corresponding author from the controlling position, even after they had some solid professional arguments.

(A1-18) The Restaurant outcrop, also visited by Prof. E. Jardim de Sá, was studied in detail by the corresponding author aiming to prepare his MSc Dissertation. Nevertheless, due to the final years (1990-2000) of operation in the Caraíba open pit, the place is now underneath a huge pile of Cu-barren rocks.

(A1-19) The three diagrams of Fig. 26 reproduce in more detail what is portrayed in Fig. 18 of the MSc Dissertation by D'el-Rey Silva (1984). Credit should also go to Prof. Emanuel Ferraz Jardim de Sá (UFRN—Brazil), who explained that complex feature for the first time to a group of his students (including Luiz D'el-Rey) during a visit in July 1984.

(A1-20) Invited by the corresponding author, Geologist José Acúrcio Canário de Moraes and Technician Raimundo Belo also took part in the mapping exercise of the Airport outcrop. The latter carried out the topographic survey with the aid of a plane table and alidade while the two geologists in the crew performed the geological study.

(A1-21) From December 1984 until the last day of 1988, the corresponding author became Manager of the Regional Exploration Division, leading a team of six geologists in the CMSA office in Salvador. Simultaneously he also became the Mine Planning Superintendent at Caraíba, dividing his time between the two places, every week.

(A1-22) After the mine geologists put on the table the massive set of new data derived from both the surface and underground mines between 1985 and 1988, Alexandre Magno Rocha da Rocha remained an entire day asking for attention to new data from a specific part of the underground Mine, wondering if these would support or deny the mushroom model established in D'el-Rey Silva (1984). Finally, as the corresponding author could see the data directly in the underground Mine, together with Alexandre Magno, the two geologists could elaborate the maps shown in Fig. A2-5 (Appendix 2) and ended up producing the paper reporting the re-evaluation of the orebody, together with other colleagues in the Mine (see D'el-Rey Silva et al., 1988). Alexandre, to

whom the Caraíba Project owes much of its success, currently teaches Geology in the EFRN, in Natal. He also published a well-reputed book dealing with geochemistry and prospection of mineral deposits.

(A1-23) As soon as the whole set of new vertical cross sections was completed in 1988, the corresponding author had to convince other geologists of the team at Caraíba that the radical change in interpreting the geometry of the central part of the orebody was a mandatory risk, considering that the Caraíba mushroom had been proved after four more years of mining (1984-1988) and the bumerangue and mushroom folding interference pattern would not survive for such a long time if it were inadequate. Consequently, everyone should be aware that, though it could initially be scary, the appearance of features similar to concentric balls in the cross sections (see Fig. A2-5 B; Appendix 2) was a simple consequence of the bumerangue and mushroom fold interference pattern and F3 tight folding. In the sequence of events, everybody felt encouraged to support the radical changes in the geometry of the mineralized layers because of the sound theoretical support.

(A1-24) The decision on the location and orientation of each diamond drill hole in the Caraíba underground in the years reported here was taken by the same team of geologists in the Mine Geology Division (see names in A1-12 above), but always based on the fold interpretation introduced by D'el-Rey Silva (1984) and the updated sections produced in the incoming years. Here should be emphasized the participation of Wilson Miola, a brilliant engineer-geologist and mathematician, who eventually overcame the corresponding author in discussing how a specific vertical slab of mineralized rocks could be better interpreted in a cross-section composing the MSc Dissertation in 1984. Miola was also responsible for controlling the path followed by each diamond drill hole in space, a fundamental

step for applying Geostatistics in computing ore reserves, another of his duties at Caraíba. After leaving Caraíba, by the end of 1986, Wilson Miola got his Master's and PhD degrees at the Pennsylvania State College, USA, and worked as a skilled professional in the USA, Mexico, and Chile until 1988, becoming a university professor and consultant for mining companies on his return to Brazil, in 1998.

(A1-25) The short- and middle-term planning in a mine relies on the position of the mineralized layers in space (which is provided by cross-sections and maps) and on the potential of ore reserve to be extracted from every slab of rock. The accuracy of this information, which is the responsibility of the geologists in charge, is vital to Mine Managers, Superintendents and Directors. Nevertheless, as these people are not geologists in general, they are not concerned with geological models, whatever they are. Nonetheless, they are professionally in charge to be very interested in positive results that depend on the work of geologists. The consequences would have been severe if the geologists had refrained from modifying the cross-sections in 1988. The Mine Geology Division would have faced significant charges for the recurring errors in mine planning because some galleries planned to reach mineralized layers in the underground mine would have driven the mining engineers and high-cost equipment into Cu-barren rocks when they were opened in the incoming years. Moreover, mineralized layers would have been overlooked, leading to a loss of valuable Copper content.

(A1-26) Dating the amphibolites in the Airport outcrop was only possible because Prof. Elton L. Dantas (Laboratory of Geochronology and Geodynamics, Universidade de Brasília) was particularly interested in extracting zircons from the scarce population in the samples of basic rock collected by the corresponding author in 2000.

End of this Appendix