# PRECAMBRIAN AURIFEROUS QUARTZ-PEBBLE CONGLOMERATES IN BRAZIL

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ABSTRACT: Auriferous quartz-pebble conglomerates were identified at Jacobina, Moeda and Goiás Velho, in Brazil, where they occur in intimate association to greenstone belts, and are related to the later phases of lithological accumulation and tectonic development of the host gneiss-greenstone terrane. They are pyritiferous and of fluvial origin, although at Moeda some previous gold accumulation occurred on the pre-sediment pavement. Variation on the source areas and on the local environment of deposition produced alternation of barren, unpay and pay conglomerates.

RESUMEN: Los conglomerados auríferos identificados en Jacobina, Moeda y Goiás Velho, en Brasil, son Precámbricos y relacionados a greenstones. Ellos fueron depositados en regimenes fluviales que occurrieron al término de los ciclos de acumulación litológica y de tectonismo que caracterizan los terrenos de gneis y greenstone que los contienen. La formación de conglomerados, con o sin oro, fue muy dependiente de variaciones temporales en las áreas fuentes de los sedimentos y en las condiciones locales de deposición sedimentaria.

## INTRODUCTION

Quartz-pebble pyritiferous and auriferous conglomerates occur in shield areas of the States of Bahia, Minas Gerais and Goiás, in Brazil (Fig. 1), and are related to terminal phases of development of Precambian greenstone belts. Only those of Jacobina, in Bahia, are being mined.

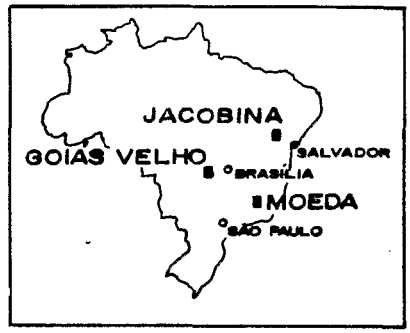


Fig. 1. Location of Jacobina, Moeda and Goiás Velho areas.

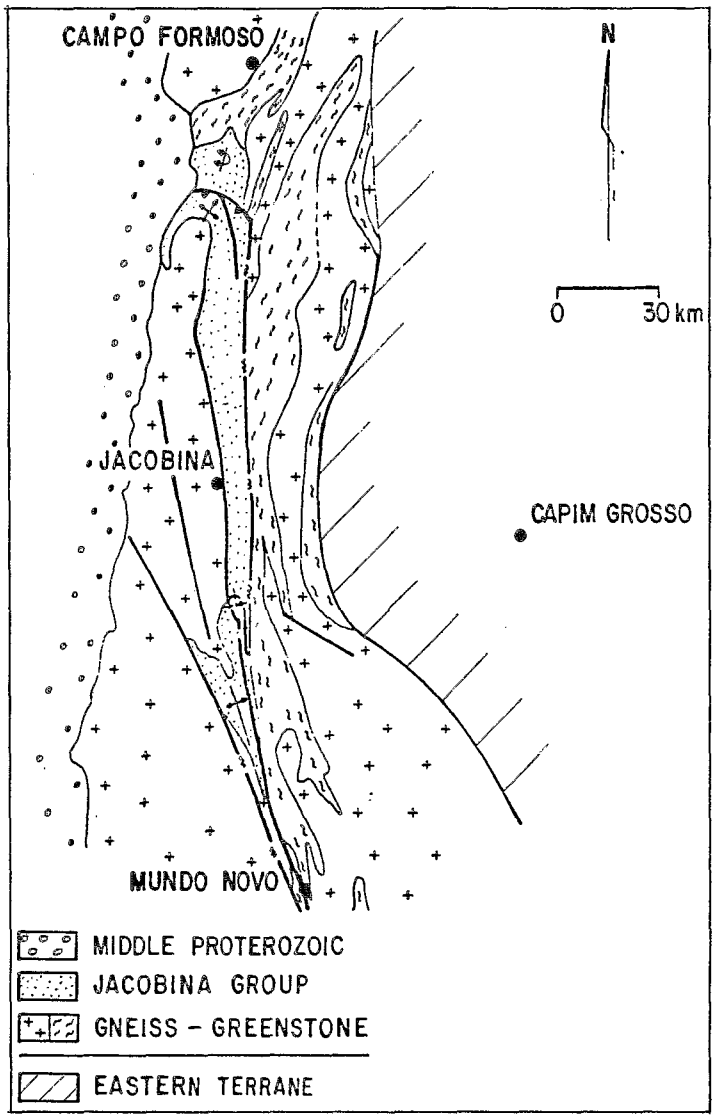


Fig. 2. Regional geology of Jacobina. The gneiss-greenstone terrane that contains the Jacobina Group is partially overlain at West by Proterozoic sediments. At East it is in contact with a granulitic terrane. At South and North, the Jacobina Group is folded due to strong compression from the Southeast; at center it presents a homoclinal dip to East.

## JACOBINA, BAHIA

### THE JACOBINA GROUP

At Jacobina, the conglomerates occur in the basal section of the Jacobina Group, a 3.5 kilometers thick and 130 kilometers long sedimentary wedge, deposited on a North-South rift, developed on a gneiss-greenstone terrane (Fig. 2). The Jacobina Group was deformed by strong compressive forces from the East-Southeast, what conforms to the North-Northeast fold axes of the underlying greenstone belts, and at its upper section it contains flows of mafic

volcanics. Both the compression and the volcanism are attributable to the wanning stages of development of the gneiss-greenstone environment.

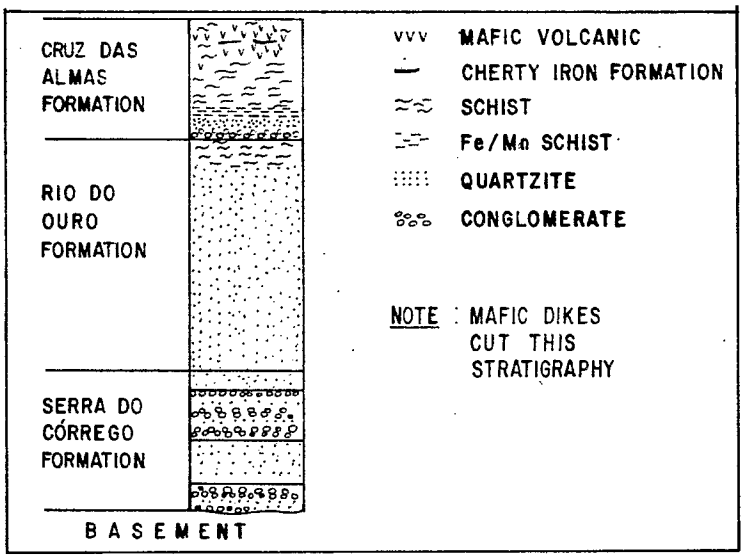


Fig. 3. Stratigraphic column of the Jacobina Group. Auriferous conglomerates are restricted to the Serra do Córrego Formation, at the base of the column. Mafic volcanics appear in the Cruz das Almas Formation.

At the base of the group, the Serra do Córrego Formation, with 260 to 850 meters of thickness, is made of upwards fining cycles of deposition, with conglomerates passing up to quartzites. Remarkably, there is only one narrow layer of shale. The quartzites and the conglomerates are very clean and mature, both composed mostly of quartz, with minor heavy minerals in the conglomerates and occasional sericite in the quartzites. They were deposited on a braided stream system, which flowed from the East to the West, into the rift.

Overlying the Serra do Córrego, the Rio do Ouro Formation, with 2,000 meters of thickness, is composed by marine clean quartzites, with about 60 meters of metapelites at the top. Ripple marks near the base indicate a transport direction from West, to East.

Above it, the Cruz das Almas Formation has more than 800 meters of thickness, and starts with a basal immature layer of conglomerate, with boulder-size pebbles of the Rio do Ouro Formation. With less than 200 meters of thickness, the formation grades from conglomerates to quartzite, to metasiltite, and to manganese and iron rich metapelites. Its upper section is marked by the presence of mafic volcanic flows, and units of cherty iron formations.

The group suffered strong compression from the East-Southeast, and was fractured, faulted and pushed to the West, assuming at Jacobina a homoclinal position, with dips of 55° (Serra do Córrego Formation) to 85° (Cruz das Almas Formation) to East. Mafic dikes filled the deeper planes of faulting and probably represent the feeder of the mafic flows that occur in the upper part of the Cruz das Almas Formation.

## THE SERRA DO CORREGO FORMATION

The Serra do Córrego Formation (Fig. 4) outcrops along 35 kilometers of strike, thinning out to North and to South. Itapicuru, where the better mineralization occurs, is at

about the middle of this length, and corresponds to the center of stream deposition in the rift (Fig. 5). As the sedimentary pile was being accumulated, the alluvial fan gradually expanded to the North and to the South, with the conglomerates becoming more lenticular, tongue-like shaped, and spreaded over the fan belt.

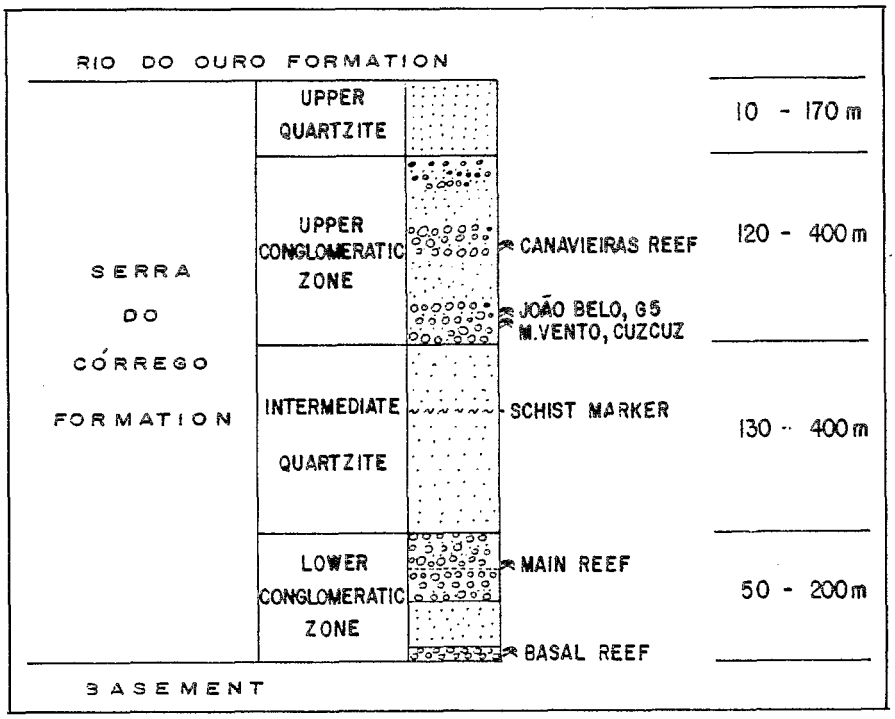


Fig. 4. Stratigraphic column of the Serra do Córrego Formation at Jacobina. The approximate position of the main auriferous conglomerates, presently being mined, is shown. The majority of the lenses of conglomerates are barren of gold or of low grade.

There is a large variety of quartz-pebble conglomerates at Jacobina, the variables being the pebble size, from gritty to bouldery, the pebble color, from the dominant white to the rare yellow and reddish, the matrix, from pure quartz sand to heavy-minerals-rich, or pyritiferous. Usually the pebbles are well packed and well to very well rounded and sorted. As evidences of the fluvial regimen, there are channel scouring and filling reworkings, channel planar to through cross beds, upwards pointing pebbles etc.

Striking features of the Serra do Córrego Formation, besides the abundance of conglomerates, which at Itapicuru constitutes more than 10% of the column, are the near absence of pelites and the scarcity of silicates, making the unit almost monomineralic, with quartz. This indicates a very mature source area, and an energetic fluvial regimen of deposition. Another important feature is the alternance of barren and mineralized conglomerate layers, with the dominance of the former. This indicates changes of source areas, changes of flow paths, and/or small size of the primary auriferous source deposits.

The formation initiates with the Basal Conglomeratic Zone, followed by the Intermediate Quartzite, the Upper Conglomeratic Zone and the Upper Quartzite. As the layers strike North-South and the paleo-channels are oriented East-to-West, the strike length of the individual conglomerate layers actually represents their width, measured across the valley bottom.

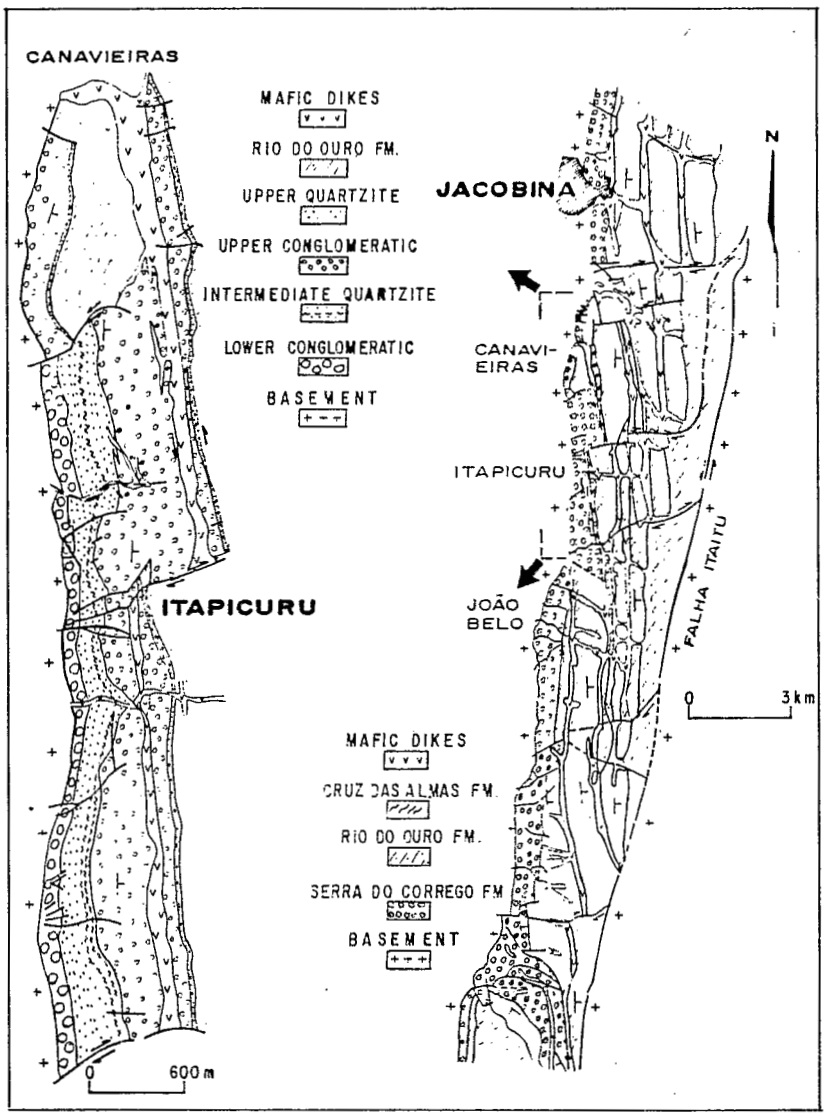


Fig. 5. Two views of the auriferous area of Itapicuru. At right a geological map of the Jacobina Group, and at left a map of the Serra do Córrego Formation. The units are heavily displaced by faults, with mafic dikes occupying fault planes. Itapicuru is sited at about the middle of the 35 km long Serra de Córrego Formation, and is the area where mineralization is stronger. It is also the only point where there is mineralization at the base of the group.

## THE BASAL CONGLOMERATIC ZONE, THE INTERMEDIATE QUARTZITE

The basal Conglomeratic Zone has up to 270 meters of thickness and extends for 26 kilometers, presenting several cycles of conglomerate-quartzite deposition. Their lower cycles extend for only 1.6 kilometers, and constitute a 25 meters thick section of coarse to very coarse pebble conglomerate layers, deposited under strong torrential conditions, representing the initial infilling of the depository. The Basal Reef is the only economical conglomerate of this section, with 4.5 g/t Au, a thickness of 4 meters and a strike length of 300 meters. This basal section is covered by an up to 100 meters thick quartzite, which is centered at about Itapicuru and extends over about 4.5 kilometers.

Above, in an 150 meters thick conglomeratic section, the only economical concentration is found in medium to small pebble layers, in what was named the Main Reef Zone (Fig. 6).

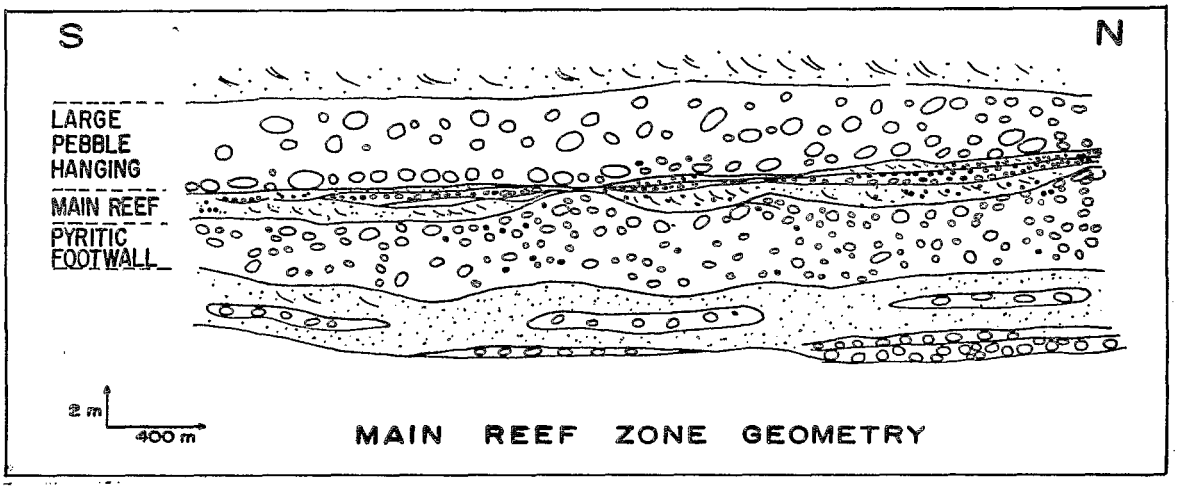


Fig. 6. Geometry of the Main Reef Zone. Both the pyritic foot-wall and the large pebble hanging-wall conglomerates are barren of gold. Mineralization is restricted to small to medium pebble conglomerates occurring in a quartzite sited between these two units.

The Main Reef Zone has a remarkable continuity on its pattern for more than 3 kilometers, and is also centered at Itapicuru. It shows a massive and pyritiferous, but barren, well round and well packed quartz-pebble conglomerate at base, a quartzite containing the mineralized conglomerates, and a also barren coarse pebble conglomerate at the top. The Main Reef itself, which is hosted in the quartzite, has a thickness of 2 to 3 meters, and an average grade of 5.7 g/t Au.

The overlying Intermediate Quartzite has a thickness of up to 400 meters, and just above its middle part it contains the Schist Marker, a few meters thick metapelite, the only one in the Serra do Córrego Formation.

## THE UPPER CONGLOMERATIC ZONE, THE UPPER QUARTZITE

The Upper Conglomeratic Zone contains hundreds of layers of conglomerates on its 120 to 400 meters of thickness, and it extends along all the extension of the Serra do Corrego Formation. It has two important quartzite layers, which split it into a lower, an intermediate and a upper unit. There are economical conglomerates in the lower and in the intermediate units, but none in the upper. The mineralized conglomerates of this zone are tongue-like shaped, and conforms to braided stream valleys atop the alluvial fan.

The lower unit presents the important Joao Belo deposit, actuallly constituted of three distinct and superposed mineralized conglomerate layers, with a mineable grade of 2,8 g/t Au over a combined thickness of 6 to 10 meters, and a strike length of 700 meters. The Joao Belo deposit is being mined open-cast and underground.

Other deposits in this unit are the Morro do Vento (Fig. 7) and Cuz-Cuz reefs, with 1 to 2 meters of thickness and grades of 4 to 6 g/t Au, and the G.5/SCO (Fig. 8), where the upper 0.5 meter of a thick conglomerate presents local enrichments, due to winnowing of sand and trapping of gold.

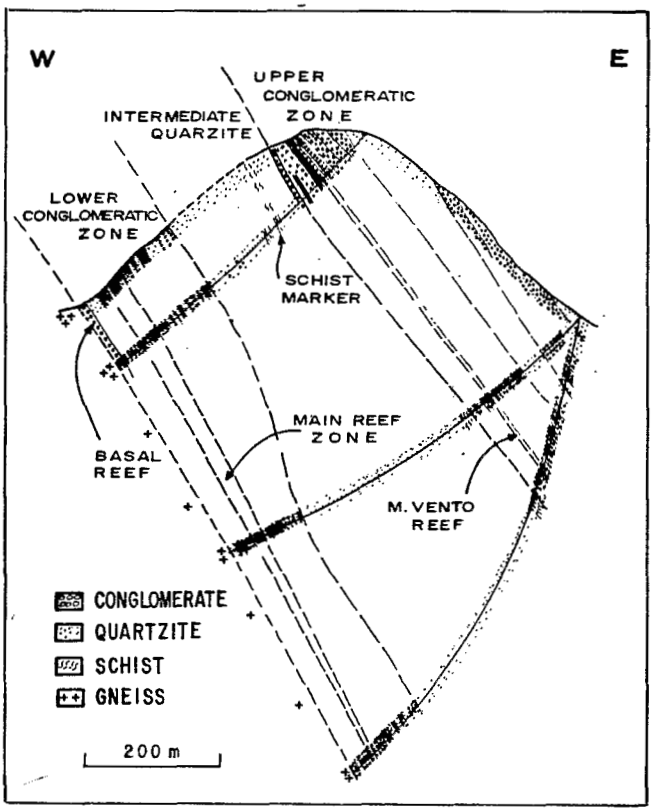


Fig. 7. Geological cross-section of the Moro de Vento hill, East of Itapicuru. The location of the Basal Reef, the Main Reef Zone, and of the Morro do Vento Reef in the Upper Conglomeratic Zone are shown. These layers have their maximum extension on the dip, as they were deposited by stream currents which flowed from the East (right) to the West (left).

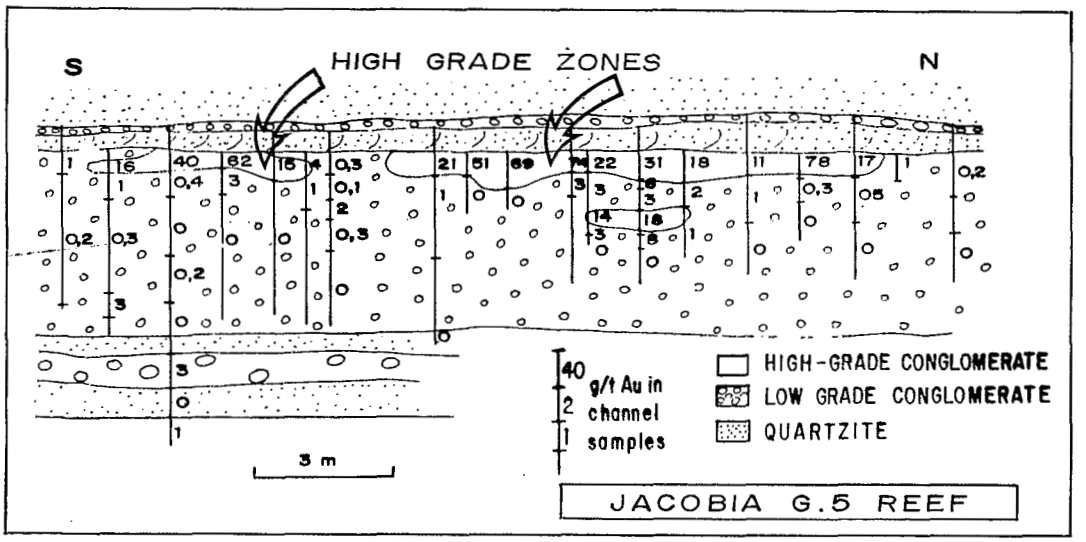


Fig. 8. Partial longitudinal section of the G.5/SCO conglomerate layer, on the Upper Conglomeratic Zone. Channel samples and assay results in g/t Au show strong top concentration of gold, by fluvial reworking, below a quartzite layer with marked through cross-bedding.

The intermediate unit contains the important Canavieiras reef, a 0.5 to 2 meters thick pyritiferous conglomerate, with a quartzite interlayer and a grade of 8 g/t Au.

The conglomerates of the upper unit of the zone represent the wanning stages of conglomerate deposition, or of fan building. They are thinner and made of small pebbles, some are pyritiferous, but none reach economical grades. Gradually they pass upwards into the Upper Quartzite.

## MOEDA, MINAS GERAIS

The Iron Quadrangle, in the State of Minas Gerais, is well known for its deposits of gold, in Archean greenstone rocks, and of iron, in Proterozoic metasediments. The Proterozoic was deposited on a nearly orthogonal system of rifts, developed on already metamorphosed greenstones. The complete pile of rocks, Archean and Proterozoic, was further deformed by compressive forces from the East, before reaching tectonic and metamorphic stability. The former rifts are now represented by overturned synclines.

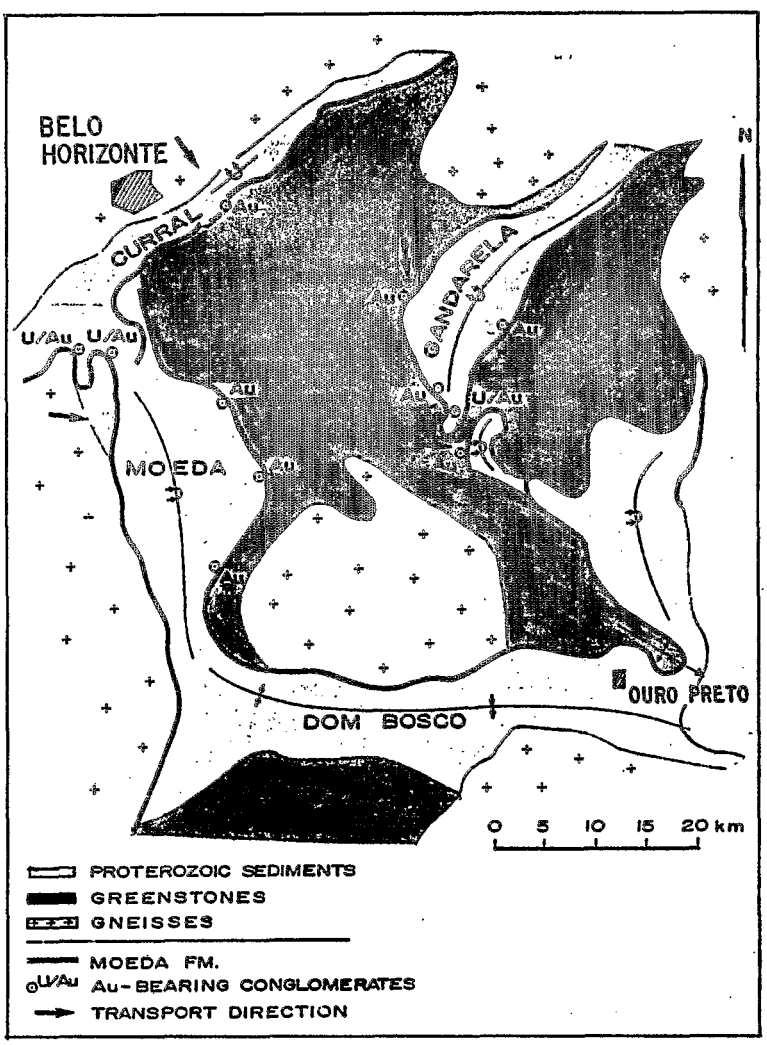


Fig. 9. General geology of the Iron Quadrangle. Archean greenstone contains auriferous lodes (not shown), and is covered by Proterozoic meta-sediments, at base of which there are quartz-pebble pyrite-rich conglomerates locally with gold or uranium-gold mineralization. Transport direction was mostly from the basement gneisses towards the greenstone area. Note the location of the Gandarela syncline, in the middle of the greenstone area.

The Caraça Group, at the base of the Proterozoic, is made by a sequence of quartzites (the Moeda Formation) at base, capped by metapelites (the Batatal Formation), below the itabirites which make the Cauê Formation. In several places there are layers of conglomerates at and near the base of the Moeda Formation. Most often, the conglomerates occur in paleo-valleys, and appear as superposed conglomerate-quartzite fining upwards cycles. They were obviously deposited by fluvial systems discharging on the rifts.

The conglomerates may reach thicknesses of a few meters, are mostly made of round quartz-pebbles, of small to medium sizes, rarely bouldery, with a sandy matrix and some sericite. Pyrite is common, as round nodules or euhedral grains. Usually pebble supported, they may grade into pyritic pebbly or gritty quartzites.

The better gold concentration known occurs in the Gandarela Syncline, which is located in the middle of the greenstone area, and appears with an intimate association of uranium and gold. The better grades are usually restricted to the very zone of contact with the footwall greenstone, as, in most of 20 centimeters of sediments, be it mature or immature conglomerate, or even quartzite (Fig. 10). In some areas, gold accumulations are not restricted to paleo-valley bottoms and are seen on paleo-slopes, at the very surface of contact between footwall schists and hanging-wall quartzites or conglomerates (Fig. 11).

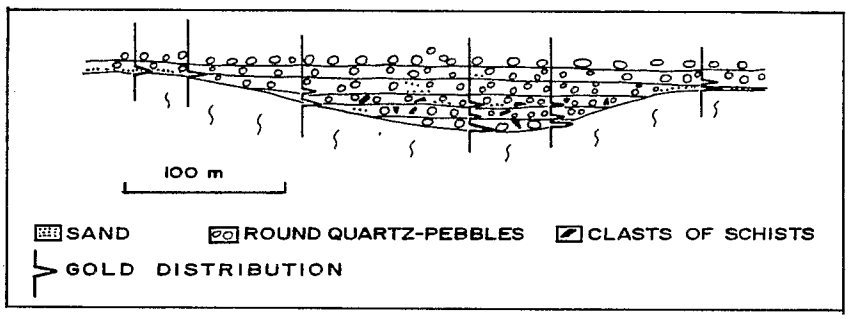


Fig. 10. Deposition of conglomerates and sandy layers on paleo-valleys on the Gandarela Syncline. Conglomerates at the bottom of the valleys might be polymitic. Gold concentrations are represented by inflections to the right of the vertical lines. Gold values are restricted mostly to the basal contact, rarely appearing in the overlying conglomerate-quartzite cycles.

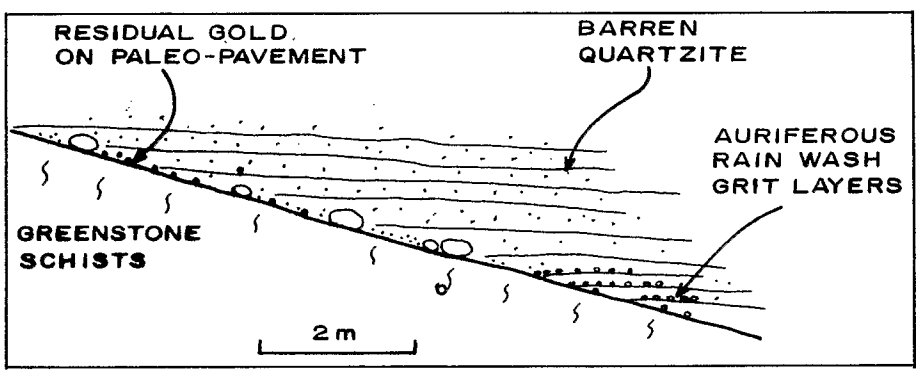


Fig. 11. At the Gandarela Syncline, residual gold on the paleo-pavement, some of which preserved under barren quartzites. Rain wash caused short auriferous gritty layers entering the valley.

It seems clear that when rifting and deposition started, the Gandarela area was close to good mineralized areas, and, in addition, there was there surperficial concentrations before sedimentation started. Some of these were buried by the sediments, but most were rapidly washed away and accumulated with the first layer deposited on the valley bottoms, and little of which was later reworked and reconcentrated.

Other basal auriferous conglomerates of the Moeda Formation are known in the Moeda and the Curral Synclines, but besides their smaller size, they are of low grade. They appear at the edges of the greenstone basin, and were deposited by rivers flowing from the basement into the rifts. It looks as there was no good source are to them.

## GOIAS VELHO, GOIAS

At Goiás Velho, State of Goiás, a 70 x 10 kilometers belt of Archean greenstone has as its upper unit an 1.5 kilometers thick pile of pyritiferous and mildly sericitic quartzites. Cross-bedding and ripple marks indicate that the sediments were transported from the basement area. The greenstone rocks and the quartzites appear synchronously folded into synclines.

At the middle third of the quartzites, there is a 50 meters thick sequence of very clean quartzites, containing, along 600 meters of strike lenght, several meter thick lenses of medium to small size quartz-pebble conglomerates. They are well sorted and classified, quite pyritiferous. The conglomerates mark the paleo-path of a stream.

Some of the layers of conglomerate shows attractive grades, from 2 to 15 g/t Au, but usually they are narrow, with less than one meter of thickness, and have small lateral continuity. Most are barren of gold or present values of less than 1 g/t Au (Figs. 12 and 13). Usually, enrichments of gold are accompanied by enrichments of uranium.

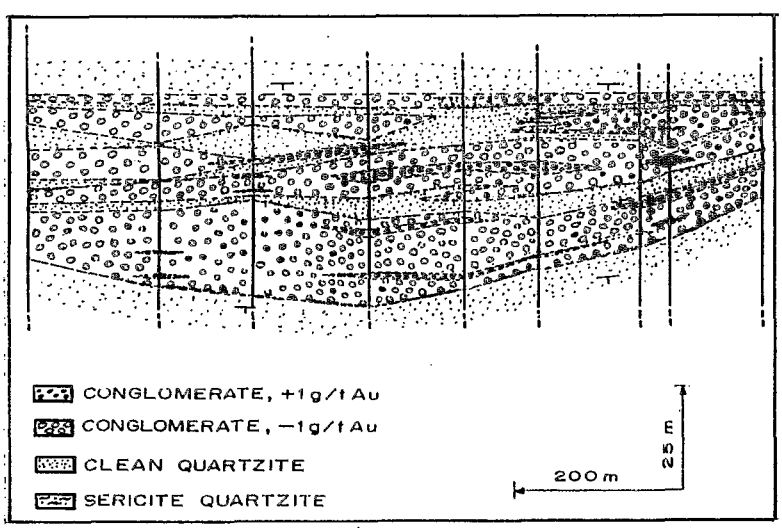


Fig. 12. Composed longitudinal section of the auriferous conglomerates of Goiás Velho. Drill holes are shown as vertical bars. The layers with +1 g/t have less than 300 meters of width and one meter of thickness.

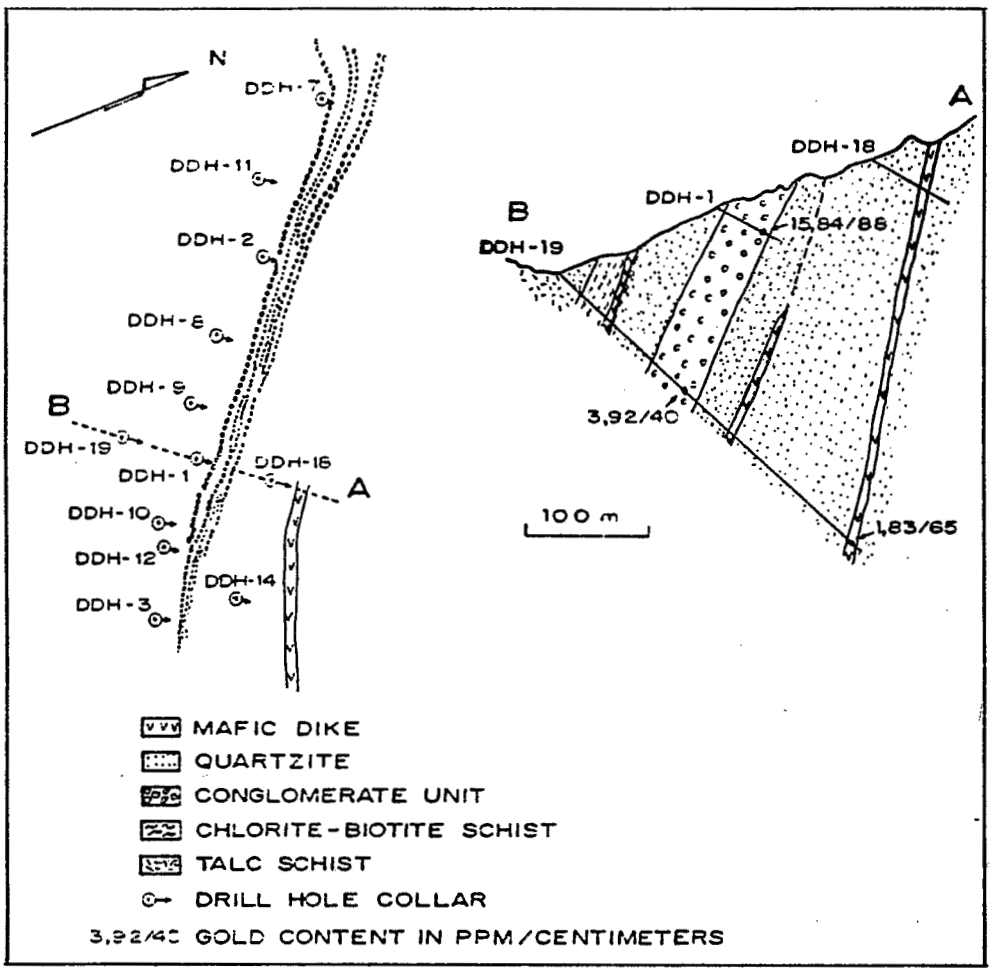


Fig. 13. Map, at left, and cross section, at right, of Goiás Velho. The mineralized conglomerates are quite scarce. A diabase dike presents gold following a silicified fracture. The structure is of an overturned syncline, and the greenstone rocks are shown at right.

In the conglomerates, there are dark carbonaceous clasts enriched in pyrite, gold and uranium, and there are suggestions that they represent concentrations of organisms. Unbroken material of similar nature, forming centimeter-size well preserved organic-like structures were seen in the quartzites.

## SUMMARY

Summarizing, the main observations emphasize:

- The close relationship of the conglomerate-quartzite suite with greenstone belts.

- The actual presence of greenstone rocks in the source area of the better mineralized conglomerates.

The presence of pyrite as a common constituent.

- The maturity of the source area, expressed by the scarcity of grains of silicates and the thickness of the quartzites.

- The high energy of the system of deposition, washing out the clayous materials.

- Possible previous surficial accumulation of gold, by weathering or by organic processes.

## ACKNOWLEDGEMENTS

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