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First Worldwide Diamond Deposit Mined in a Rock

Mario Luiz de Sá Carneiro Chaves[1]
Leila Benitez[2]
Kerley Wanderson Andrade[2]

[1] Centro de Pesquisas Prof. Manoel Teixeira da Costa, Instituto de Geociências da Universidade Federal de Minas Gerais. Av. Antônio Carlos 6627. Belo Horizonte – MG. CEP 31.270-901. Pesquisador CNPq.
E-mail: mchaves@igc.ufmg.br .
[2] Instituto de Geociências da Universidade
Federal de Minas Gerais. Av. Antônio Carlos 6627. Belo Horizonte – MG. CEP 31.270-901.
E-mails: leilabenitez@gmail.com , kwandrade@yahoo.com.br .

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Pedra Rica (the Rich Rock) is located in Grão Mogol, a little town in the north of the State of Minas Gerais. It represents the first place in the world where diamonds were found and exploited in a rock. This remarkable event occurred around 1827 and is of historical importance, since until that time diamonds only were mined from gravel in stream beds. Pedra Rica crops out at the northeastern part of the town and represents a 10 m long and about 2 m thick lenticular bed of metaconglomerate, on the western slope of a hill bordered by the Córrego (creek) dos Bois. This metaconglomerate and other ones that occur in the region belong to the Grão Mogol Formation, a basal sedimentary unit of the Espinhaço Supergroup, which was layered down in a rift type basin developed between ca. 1,75 Ga and 1,30 Ga. A remarkable erosive discordance is observed between the conglomeratic unit of probably fluvial origin, cutting large sets of cross stratification of the basal Resplandecente Formation. Diamond mining in the area became very limited after the creation in 1998 of the Grão Mogol State Park. Since then a campaign of awareness do occur in the city, to preserve the geohistorical sites representing the main remainder of the mining epoch and at the same time to stimulate the ecotouristic activity.

Keywords: Pedra Rica; metaconglomerate, diamonds; Espinhaço Supergroup; Minas Gerais.

INTRODUCTION

The small town of Grão Mogol is inserted in the context of the Espinhaço Range, in the north extremity of Minas Gerais, being considered the more northern historical locality of this State. In the first half of century XIX, the scientific interest for this region was initiated with the worldwide discovery, of diamonds hosted in a rock-type; all the known deposits until then were of alluvial type. Such finding called the attention of diverse foreign researchers, being distinguished the Austrian geologist and engineer of mines Virgil von Helmreichen, whose main workmanship is one of the most important written documents already on diamonds of Brazil, and where this author already displayed clearly the relationship between the diamonds and the "itacolomites with conglomeratic aspect" in the region (Helmreichen, 1846). Since then, the most important of these bodies, assigned as Pedra Rica (Figures 1 and 1A), was extensively mined; however rests of such mineralized rock still are found in the place and it had become a municipal patrimony now. In this manner, for its geoeconomic importance and international recognition, Pedra Rica is considered as a geologic site and a landmark of the diamond mining in Brazil as well as in the world.

According to Wikipedia (2006), there are two versions to the origin of the Grão Mogol name: the first one is related to the discovery in 1550 of a great diamond found in India, with weight of 793 ct and that it was called "Great Mogul". However, for Harlow (1998), this same diamond would weigh 787 ct. The second version relates the name to the fact to have existed innumerable conflicts, clutters and murders in that region, giving origin to the name "Grande Amargor" (Great Bitter), which modified locally would have transformed into Grão Mogor and later assuming the current denomination (Wikipedia, 2006). Interesting to observe that the older bibliographical references use the assignment "Grão Mogór" (eg., Helmreichen, 1846; 1847).

LOCALIZATION

Grão Mogol town is placed near 550 km from the state capital, Belo Horizonte, in the north extreme of Minas Gerais (Figure 2). The distance covered since the capital begins through the BR-040 road (Rio de Janeiro to Brasília) until the São José da Lagoa junction, after Paraopeba town, when the BR-135 road is overcome passing by Curvelo, Buenópolis, Bocaiúva, and Montes Claros towns. In the last locality, cross by the BR-135 road to Salinas town direction, when after 77 km a junction to right go to Grão Mogol town. This last interval is precariously through of a 52 km land road. The Pedra Rica presents 42°53'W and 16°33'S coordinates, and is located near 1,700 m (straight direction) northeast of the center of Grão Mogol.

Figure 1: General aspect of the Pedra Rica hill, where in its basal portion the mined rock is placed (indicated by the arrow). A view from west to east saw in the track in direction to the Barão's mountains. **Figure 1A:** Detail of the diamond-bearing metaconglomerate outcropping in the point shown in Figure 1.

HISTORICAL APPROACH ON DIAMONDS IN GRÃO MOGOL MOUNTAINS

Diamonds were found in Brazil around 1710 in the Espinhaço Range, in the vicinity of Diamantina town (formerly called Arraial do Tejuco). The diamonds had been mined from alluvial deposits, at the same manner of the diggings in India and Borneo, the two other localities at that time with explorations in the world.

With the expansion of the diamond mining to the north direction along the Espinhaço Range, several new diamond sites were discovered. In the Espinhaço region where Grão Mogol is placed, first descriptions were made by the mineralogist José Bonifácio de Andrade e Silva, also known as the "Patriarca da Independência" (the Independence Patriarch) of Brazil, when he reported about diamond mining in the Itacambiruçú River (Silva, 1792). Spix and Martius (1828) were naturalists and princes from Prussia that visited the region at the beginning of XIX century, and reported that such discoveries occurred around 1781 in the Santo Antonio (or Grão Mogor) mountains, allowing the appearing of the Grão Mogol village.

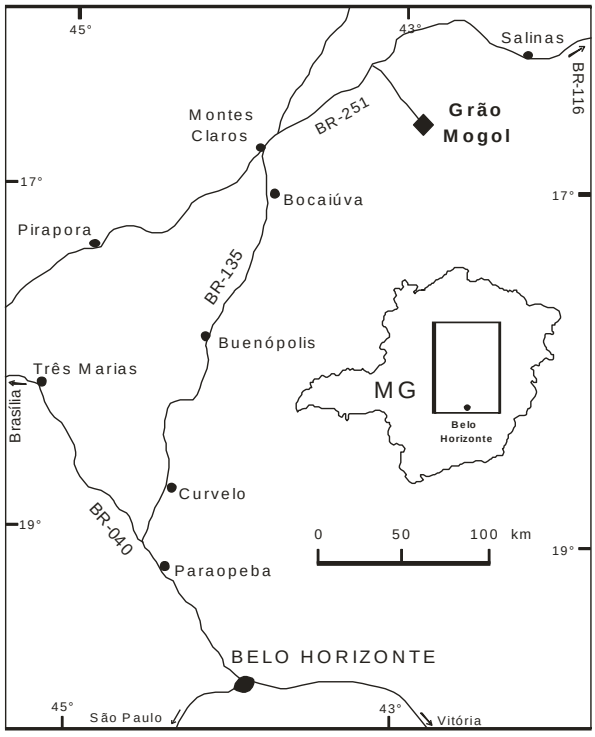

Figure 2: Map of localization and access to the diamondiferous region of Grão Mogol, State of Minas Gerais.

At the beginning of the XIX century, informal reports appear in the Espinhaço diamondiferous region, telling that in Grão Mogol proximities diamonds had being mined in a matrix-rock (Moraes, 1934). As diamonds were only discovered in the "Sopa"-type conglomerate around 1850, in Diamantina region, the discovered of Grão Mogol deposits occurred with great precedence. Although afterwards has serious doubts appeared concerning this fact, the first scientific informations about such discovery were due to the Danish naturalist P. Claussen (1841a; b). However, of major importance to the understanding of the question is the work of the Austrian engineer and geologist V. von Helmreichen (1846), when he describes the locations, mining processes, and forms of occurrence of diamonds in the Grão Mogol region. In this study the Bois creek (and others) deposits were detailed, and an adjacent conglomerate, the Pedra Rica (Figure 3), that was described as a "itacolomite with conglomerate aspect". It was no doubts that this founding represented as the first diamond-bearing rock in the world. Other historic references about the Pedra Rica are due to Heusser and Claraz (1859), Derby (1879; 1882), and Gorceix (1884a; b). Several detail works had been also produced at the 1930's decade, of whose results are found in Moraes (1934). This author studied the main diamond deposits of Grão Mogol, enclosing the geologic and stratigraphic aspects of the Pedra Rica. Their historic reports also are important: "*In 1827 was begun the mining of diamonds in its matrix-rock. In 1839 Peter Claussen visited the locality and in 1841 he sent to Royal Academy of Bruxelas magazine's a work in that described diamonds in a rock-type actually classified as a conglomerate. In 1841, Virgil von Helmreichen did a travel to Grão Mogol, because the information of the found of diamonds in such rock... he sends to Viena Science Academy a report about its travel that was published in 1846*".

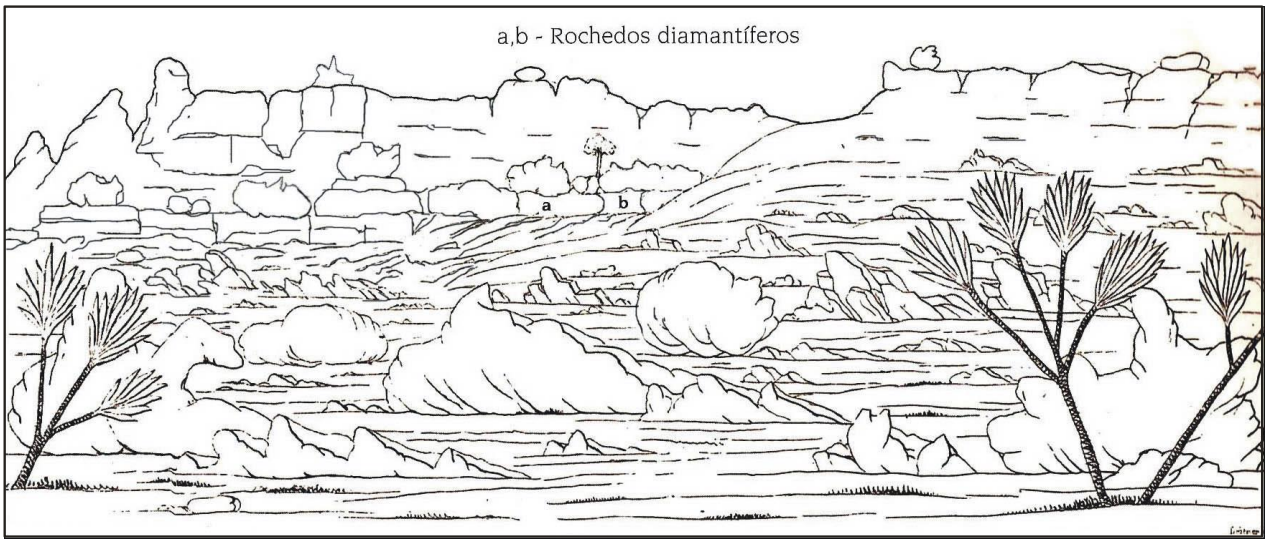

Figure 3: Extracted plate of Helmreichen (1846), showing to a sight of the Bois' creek at east, and the Pedra Rica outcrop (a, b – diamond-bearing rocks) in the basal portion of the mount.

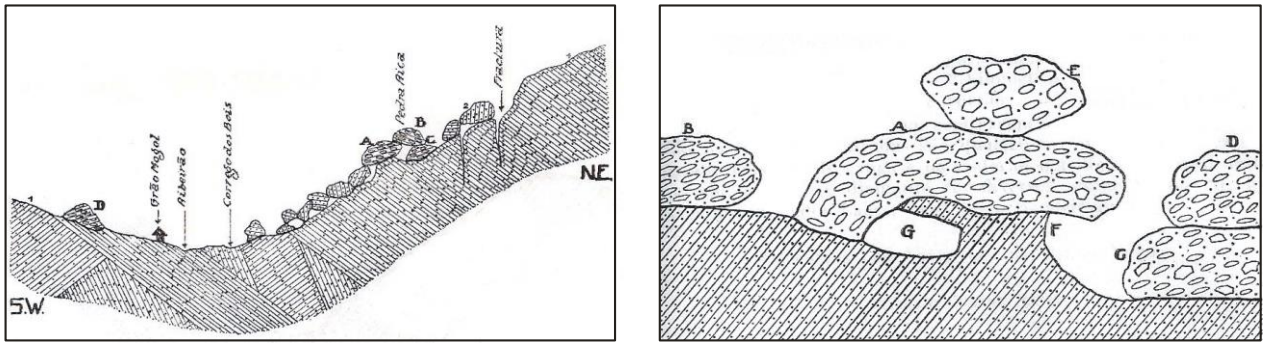

Figure 4: Extracted plates from Moraes (1934), first to the left showing a geologic section SW-NE in the Grão Mogol town area, where are emphasized quartzites with great cross stratifications covered by metaconglomerates. To the right, a detail of the Pedra Rica placed at one of these giant crossing sets.

However, in another report less known of Helmreichen (1847), the Claussen's report about the discovery of the diamond-matrix is questioned: "*I hope that my work about the occurrence of diamonds in Grão Mogol mountains that I sent to Viena at long time had been placed in the press. I have admit: sometimes I was bored because this work has remained such long time to be published, although I haven't the presumption of that it is very good, because I think that presents some errors. However I am the first – and the unique – researcher that studied the occurrence of the diamond*

matrix-rock in field, and the publication of this work can correct the falsehood that the Danish Peter Claussen had audacity of to relate to the world, being that he never tread in that local in its life. Lamentablely its work appears have been good accepted, seeing that Humboldt uses such information in its Kosmos (page 278)". These data, if are true, confirm the first scientific description of the Pedra Rica by Helmreichen."

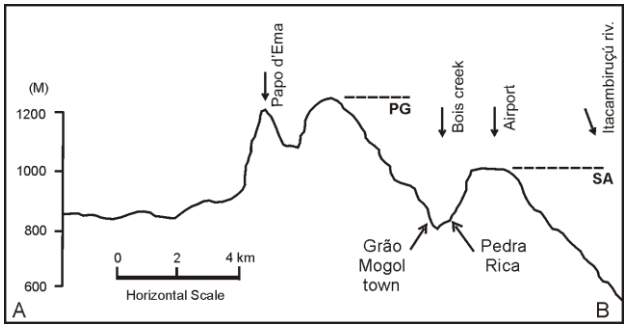

Figure 5: Topographical profile approximately east-west in the Espinhaço Range in Grão Mogol, standing out the "Pós-Gondwana" (PG) and "Sul-Americana" (SA) plain surfaces, according to King (1956) (A-B cut shown in the figure 6).

DESCRIPTION OF THE SITE

Stratigraphycally the Pedra Rica belongs to the Grão Mogol Formation (Espinhaço Supergroup), and its main features will be described according to regional geomorphology, geology, and historic and economic importance due to its content of diamonds, and also because of other similar bodies in the same area.

Physiographic Context

The Espinhaço Range presents characteristic and similar relief forms, being distinguished certain main features molded according to the type or association of rocks presents. In the west of the range, pediplain depressions characterize the domain of the Crystalline Basement. In the range zone, quartzite mainly when it present fine granulometry and high degree of maturity (a predominant characteristic in this area), show scarps with high or subvertical angles that follow a general direction north-south, concordant with the regional structure of the folds and also the planes of the prominent foliation.

Abrupt rises as landmark quarries on plane surfaces are typical of this range sector, explained for the surface erosion. King (1956) recognized cyclical plain surfaces, of which in the Espinhaço region it appear designed as "Post-Gondwana" and "South American" surfaces, respectively developed in the Upper Cretaceous and Middle-Upper Tertiary ages (Figure 5). In the neighborhoods of Grão Mogol, the ridge presents certain peculiarities due its thin for about 3-7 km, in contrast with the verified widths of 60-80 km in the region of Diamantina. The smoothed higher parts (1,200 m to 1,300 m) had been formed in consequence of the Post-Gondwana cycle. The surface around 1,000 m (South American cycle) widely appears developed to the east of the range on rocks of the Macaúbas Group, but it also occurs in restricted areas on the Espinhaço Supergroup, where it can form thin gravel pits cemented by laterites that are mined for diamonds.

Geology

Chaves et al. (1999) mapped the Grão Mogol region at 1:50,000 scale, and also made detailled stratigraphic sections from this city until Itacambira, at south. Three major lithostratigraphic precambrian sequences are distinguished: the Basement Complex, Espinhaço Supergroup (divided in the Resplandecente and Grão Mogol formations), and Macaúbas Group (Figures 6 and 7).

The Basement Complex of archean age occurs at the western side of the range, composed by biotite gneisses and migmatites. Macaúbas Group of neoproterozoic age, occurs at eastern side of the range, and is formed by graphite phyllites and impure quartzites. Both sequences will not be discussed in this work, either tertiary lateritic cover and quaternary sediments that occur in the region.

ESPINHAÇO SUPERGROUP IN DIAMANTINA AND GRÃO MOGOL REGIONS

The stratigraphy of the Espinhaço Supergroup in the Southern Espinhaço Range (Diamantina region) is well defined as a result of several studies developed in the last decades. There is a consensus about the sedimentary evolution of this sequence that was deposited initially as a rift-type basin, with transitional to shallow marine sediments in the top. The deposits that represent the rift and transitional phases are designated of Diamantina Group (a synthesis about this theme is found in Dossin et al., 1990). This sedimentary sequence was metamorphosed in low greenschist facies.

The Central Espinhaço Range in which the Itacambira-Grão Mogol region do occur is separated from the Southern Espinhaço Range by an 50 km broad area in which younger metasedimentary units related to the Macaúbas Group are reported. Helmreichen (1846) and Derby (1879) observed that the quartzitic sequence in this domain is similar to the rocks of the Chapada Diamantina (Diamantina Tableland) of Bahia, and not with that of the Diamantina region in Minas Gerais. Such difference also was note by Karfunkel and Karfunkel (1976), that recognized a special stratigraphic section, that must "*has its validity confirmed by future detail works in regional*

context", composed by the Itacambiruçú, Resplandecente, Água Preta and Matão formations, from the base to the top of the section. Geologic mapping in Grão Mogol region also no confirmed the stratigraphic column of the Diamantina area (Chaves, 1997; Chaves et al., 1999). These studies showed that do occur two unities divided by an erosive discordance, designated Resplandecente and Grão Mogol formations.

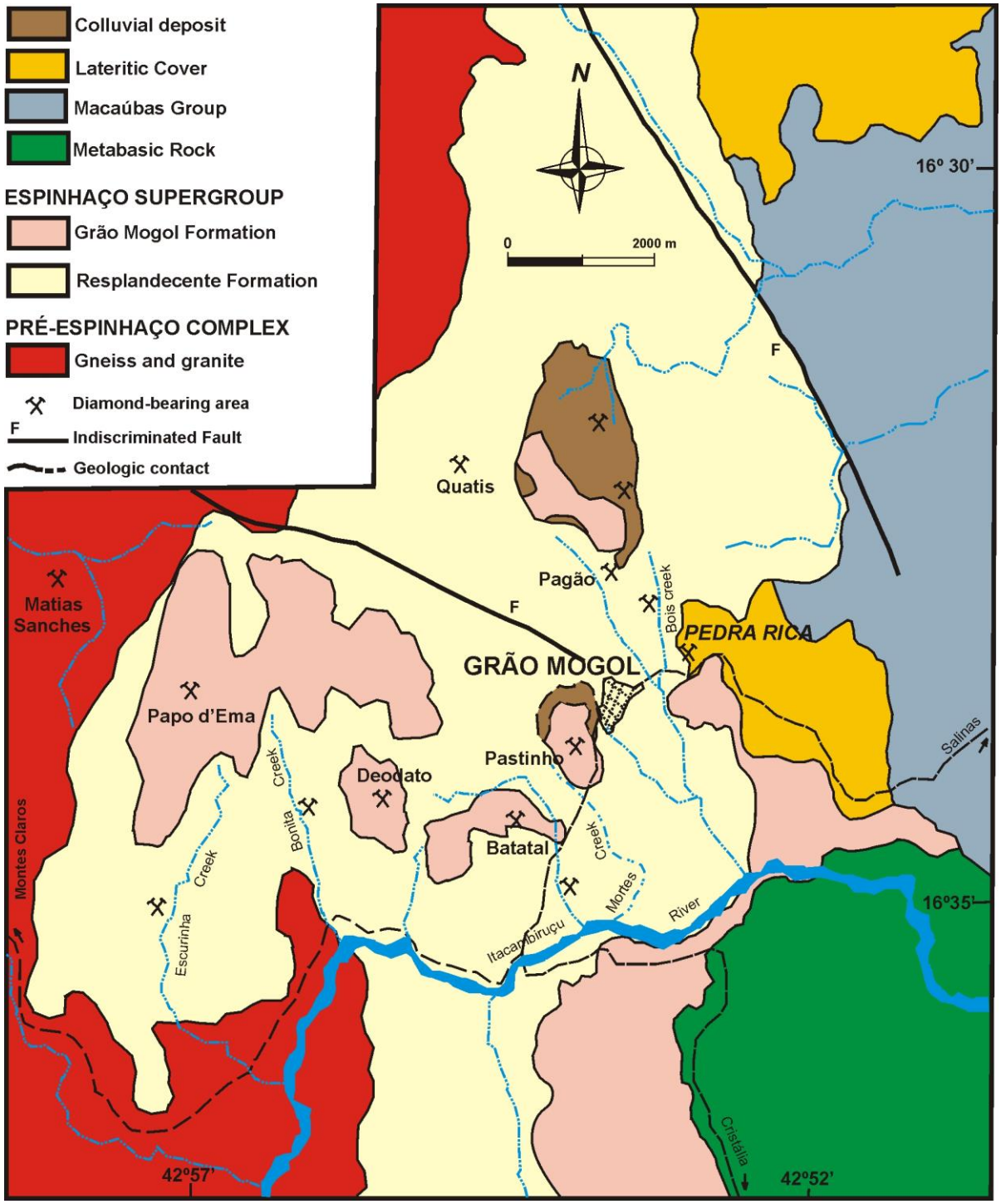

Figure 6: Geology and main diamond-bearing deposits in the Grão Mogol region (MG), according to Chaves (1997) and Chaves et al. (1999).

Resplandecente Formation

Since Diamantina to north direction, occurs a sucession of alternances of the Sopa-Brumadinho and Galho do Miguel formations. In the zone of the northern closing of the Southern Espinhaço brachyanticlinal structure, only the Galho do Miguel Formation outcrops due the depression of the fold axis in this direction. In the Central Espinhaço southern extreme, outcrops a sequence with similar characteristics of the Galho do Miguel sequence,

showing plunges of folds to south. Thus, due to stratigraphic position and lithologic and faciologic features, the Resplandecente Formation cannot be related to the São João da Chapada Formation that occurs in the Southern Espinhaço, as preliminary suggestions of Karfunkel and Karfunkel (1976) and Uhlein (1991), but to the Galho do Miguel Formation. In Grão Mogol region this unit is composed by a monotonous succession of fine and pure quartzites, with medium to large size and high angle cross stratifications. Excellent outcrops of these rocks occur in the margins of the Itacambiruçú River, near of the bridge to the Cristália town, where cross sets with ten of meters in length do occur. Quartzites with similar aspects and same stratigraphic position occur continuously to the south direction until the Itacambira-Botumirim region, where Karfunkel and Karfunkel (1976) defined the Resplandecente Formation. By their lithologic characteristics and facies associations this unit can be related to a 300-350 m thick eolic sedimentary environment (Chaves et al., 1999).

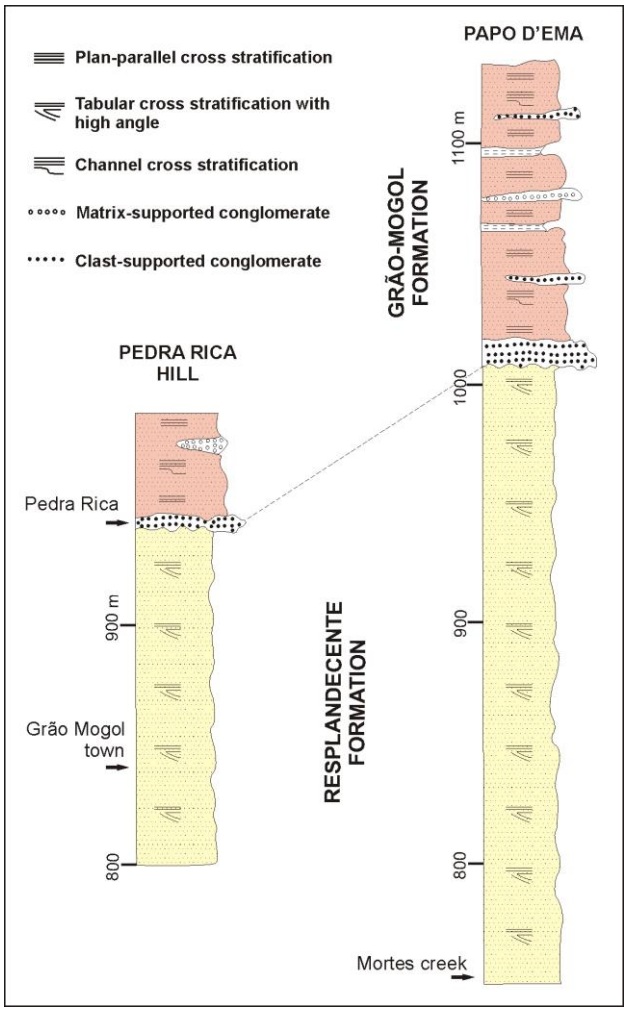

Figure 7: Stratigraphic column of the Espinhaço Supergroup in the Grão Mogol region (modified from Chaves et al., 1999).

Grão Mogol Formation

The diamond-bearing metaconglomerates that occur on extensive region of the Central Espinhaço were firstly related to the "Sopa Formation", placed in discordance with quartzitic sequence of the range, formerly related to the "Itacolomi Series" (Moraes and Guimarães, 1930). In Moraes (1934), a detailled picture is shown, in which clearly appear an angular discordance between the two units (Figure 4). In this last work, probably Moraes had observed the contact of the Grão Mogol conglomerate on the large cross-stratification sets of the Resplandecente Formation, as after confirmed by Chaves et al. (1999). Mapping surveys performed by these authors also confirmed the erosional discordance in a regional aspect, and should be followed by about 50 km since Grão Mogol until Cristália. These studies still pointed out that the Grão Mogol Formation can be divided into two lithologic levels informally designated of "Lower Member" and "Upper Member".

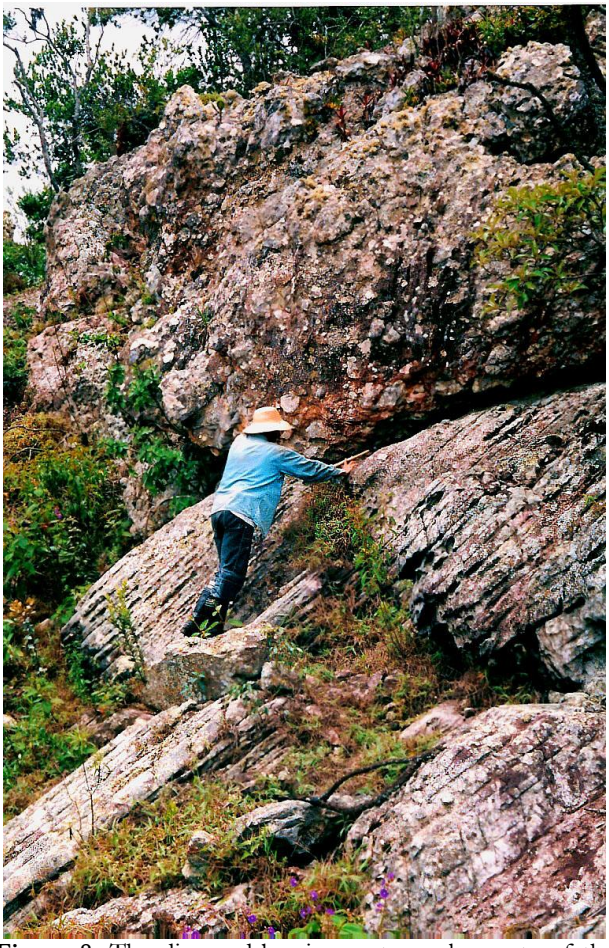

Figure 8: The diamond-bearing metaconglomerate of the base of the Grão Mogol Formation, deposited over giant sets of cross stratification of the Resplandecente Formation (locality of Papo d' Ema). Such structural effect causes the false impression of an angular discordance between these two units.

The Lower Member covers the Resplandecente quartzites on erosional discordance. Such level is composed by diamond-bearing clast-supported

metaconglomerate. This rock occurs as lenticular form as was noted in Pedra Rica hill, showing 2-3 m thick (Pedra Rica) until 8-9 m thick (Córrego das Mortes – Papo d'Ema section) lenses; in this last area the outcrops are very notable (Figure 8). Generally predominate quartzite clasts (*circa* 80-90%) and the rest are of quartz vein (Chaves et al., 1999), with 20 cm of maximum diameter, showing metamorphic interpenetration with the fine quartzitic matrix. Where the level is thicker an internal 1-2 m thick stratification in this metaconglomerate is noted, that no occur in Diamantina region.

The Upper Member of the Grão Mogol Formation cover in concordance the metacoglomerate (where it occurs), composing a sequence with fine to medium, micaceous quartzites with lenses of conglomeratic quartzites and matrix-supported metaconglomerates. Intemperized phyllitic intercalations with decimetric size were observed in the Papo d'Ema section. The common presence of mica produces a lamellar aspect to the quartzites that is emphasized with the differential erosion. The maximum thickness of this complete level is 80 m. The main primary structures are small size and low angle cross stratification, sometimes with channel structures, and ripple marks with sinuousness crests. These observed aspects indicate that the sequence was deposited in an alluvial environment.

The Espinhaço Supergroup basin in Grão Mogol region

The large distance between the Southern and Central Espinhaço domains, where Grão Mogol is placed (>200 km) is the main reason to that no occur some relation between their conglomeratic levels, which deposition characterizes episodic and local processes. So, paleogeographic features of the basin in Grão Mogol region are not similar to the stratigraphic context presented in Diamantina region. Thus, no correlation of the Grão Mogol and Sopa-Brumadinho conglomerates are based on: (a) the Sopa Conglomerate deposition occurred in alluvial fan and fan deltas environments, being such deposits typical of reduced areas in a limited tectonic context (eg. Garcia and Uhlein, 1987; Dossin et al., 1990; Martins-Neto, 1993); (b) the Sopa Conglomerate has a polymictic typical constitution while the Grão Mogol conglomerate is mainly composed by quartzite clasts; (c) stratigraphic position of the last conglomerate occur in a regional desert environment, while the Sopa Conglomerate is covered by such eolic sediments.

Although conglomerates generally occur associated with tectonic episodes in braided plains or alluvial fans related to rift, pull-apart or foreland basins, much conglomeratic deposits actually are being redefined as deposited by torrent rains in arid environments, only enclosing small portions of the basins. The Grão Mogol Conglomerate probably was deposited under such conditions, while the large desertic areas of the Resplandecente Formation were submitted to strong sporadic rains that caused the reworking of their partially consolidated deposits (Chaves et al., 1999). For these authors, this scenery could determine the formation of conglomeratic bodies with clasts of the same basin, in a braided alluvial system where diamonds also were being transported.

The Pedra Rica and diamond mining in the region

In Grão Mogol district several bodies of diamond-bearing metaconglomerates do occur, enclosed in the basal level of the Grão Mogol Formation. Although the Pedra Rica is not the most important outcrop in this region, it acquired evidence for constitute the first host-rock of diamonds described in the scientific literature; the dimension of this outcrop is about 2-3 m thick and about 10 m of width along a north-south trend. However, in the region the conglomeratic bodies are commonly 5 m thick, until 8 m like in the Córrego das Mortes (Death Creek). The most interesting expositions of the rock occur in Papo d'Ema locality where good outcrops define clearly its relation with the lower Resplandecente Formation (Figure 8). There are no data about grades or reserves in all these localities.

Figure 9: Small lot of diamonds produced in the Grão Mogol region in 2006 (stones with 0,60 to 0,90 ct), showing its excellent quality in terms of morphology and clarity.

Besides the Grão Mogol Conglomerate, diamonds are mined in the region on colluvial (or "gorgulhos") and alluvial deposits. Historic registers concerning the diamond production are scarce. Helmreichen (1846) mentioned production values of 200,000 ct/year in 1841, signifying about 20% of the Minas Gerais production at that epoch when the production of this state was largely the main of Brazil. These data indicates the importance of the region during the XIX century when more than 7,000 people lived in the

town (Helmreichen, 1846), and also because the excellent general quality of their diamonds (Figure 9). Chaves et al. (1999) estimated a regional production of 5,000 ct/year in 1992, declining to 1,500 ct/year in the 1995-1996 biennium. According to the experience of the "garimpeiros" in the town, in 2006 the production was reduced to a minimum, perhaps no more than 100-150 ct/year. Thus, there is a forecast of a rapid extinction of the activity, denoting the necessity of new way of subsistence for population that could be reached with the increase of the tourism through the creation of the Grão Mogol State Park.

Figure 10: Sight of scenic beauty of Itacambiruçú River running on eroded canyons of east-west direction, with numerous beaches in its margins. At left, the Pedra Rica hill can be observed.

PRESERVATION MEASURES

Actually the Pedra Rica site is relatively well protected in view that it is placed in the State Park of Grão Mogol. This park was created in September (22) 1998, aiming at to preserve hydrical resources, and local flora and fauna. It includes totally the mountain range in the domain of the Grão Mogol county. The Itacambiruçú River marks out the south contour of the park, and this river is also notable by no common scenic beauty (Figure 10). More than this, however, it is the fact by that in the last 10 years an increase at local level of awareness in relation to environment protection of the mountain range has been observed and its natural resources as a whole, thus the Pedra Rica also has been enclosed as a geologic heritage at municipal level in the year 2000 (Figure 11). However, people of the city has not a good knowledge of the Pedra Rica as the first worldwide diamond matrix-rock and also of its accurate localization. In this direction, we suggest that periodic lectures could be pronounced by researchers of the geosciences area to the teaching staff of basic education of Grão Mogol, including itself visits to the site, so that such fact could be told and recognized by its inhabitants, valuing the history of the mining and the geologic importance of the Espinhaço range in this region. These activities, in trust with ecotouristic activity that could be stimulated with the creation act of the Park, and thus could assure a sustentation alternative to the municipal economy, seriously affected by the decline of the digging activities.

Figure 11: Track of the Grão Mogol town in direction to the Pedra Rica hill, illustrating the informative plates in the stretch and the preoccupation of the municipality to the preservation also of the local geologic patrimonies.

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[1] Centro de Pesquisas Prof. Manoel Teixeira da Costa, Instituto de Geociências da Universidade Federal de Minas Gerais. Av. Antônio Carlos 6627. Belo Horizonte – MG. CEP 31.270-901. Pesquisador CNPq. E-mail: mchaves@igc.ufmg.br .

[2] Instituto de Geociências da Universidade Federal de Minas Gerais. Av. Antônio Carlos 6627. Belo Horizonte – MG. CEP 31.270-901. E-mails: leilabenitez@gmail.com , kwandrade@yahoo.com.br .