CONE
MINE EXPLORATION

GALINHEIRO EMERALDS PROJECT

1 - INTRODUCTION

1.1 - OBJECTIVE

The follow present report has an objective to describe the accomplished works in offices and fields for the geologic and economic description of the area referring to the Galinheiro Project of the Cone Mine Exploration. This work has a main goal elaborate an evaluation of the emeralds and ornamental granite in the process area, quantifying and qualifying them with accuracy.

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1.2 – MINERAL LEGISLATION IN BRAZIL

The laws that conduct the mining activities in Brazil established that the subsoil belongs to the federal government. That way, activities of prospection, exploration and exploitation just are possible with the government authorization through of its department DNPM (National Department of Mineral Production).

Each process of mineral exploration is evaluated by the DNPM based in technique criteria and the authorizations are granted in two stages: Exploration License and The Mine Work Concession.

The authorization holder of DNPM has full and exclusive rights about the work execution, as well about the commercialization of the area.

1.3 – MINING IN BRAZIL

Brazil stands out worldwide as one of the main producers of the minerals goods.

The mining industry in Brazil has a highest technology level and technique, being forward of a several obtained innovations in this area in the last decades.

In all regions of the country exists an extensive web of education for the formation of professional that attempt to the mining's demand. The high workforce qualification, together to good infra-structure and low productive

cost becomes the mining in Brazil object of a great interest by the part of the foreign and national investors.

Data of the IBRAM (Brazilian Institute of Mining) presented that in 2008 the Brazilian mineral sector employed 161 thousand people in the mine work activity and the value of the commercialized national production was US$ 29 billion.

Adding the commercialized rude ore production to the production of the sector of mineral transformation, the mining of Brazil generated in 2008 US$ 42 billion, what represents 5.7% of the GIP. The positive scene reflects in the investments of the sector that are foreseen in US$ 47 billion between 2009 and 2013.

1.4 – THE STATE OF MINAS GERAIS

Minas Gerais is located in the Brazilian southeast region, the most developed region of the Country. In this region are concentrated 43% of the Brazil's population, about 60% of the national Gross Domestic Product and the most significant parcel of the Brazilian Consuming Market. On this context, Minas Gerais represents the third economic power of the Country with a Gross Domestic Product (GDP) by an order of US$ 104 billion, in 2005, being 8,5% generated by the agri-stockbreeding, 48,6% by the service sector, which grew significantly in recent years, and 42,8% by the industrial sector.

1.4.1 Geographic Aspects

The state of Minas Gerais is located in the Brazilian southeast region. As the mediterranean area, Minas Gerais make boundary with states of São Paulo, Rio de Janeiro, Espírito Santo, Bahia, Goiás, Mato Grosso do Sul and Distrito Federal, comprising 588.384 km^2.

The prevailing climate is the tropical of altitude, with rainy and dry stations well defined. The annual average temperatures vary around 18°C and 25°C. The annual average pluviometric precipitations vary between 800 mm in the extreme north and 1,700 mm in southeast of the state.

With 18 million of inhabitants, the population of Minas Gerais is the second bigger of the Country and distributes around 853 counties. The capital of the state is Belo Horizonte, with 2,5 million of inhabitants.

The State is geopolitically shared in region of planning, with features well defined: Zona da Mata, Sul de Minas, Triângulo Mineiro, Noroeste, Centro-Oeste, Jequitinhonha/Mucuri, Rio Doce, Alto Paranaíba e Região Central.

The city of Itabira and the area of the Ribeirão São José Project are located in the Central Region. With a Mountainous relief and privileged climate, this region is one of the richest of the country in the mineral resource, having importants explored reserves of iron, gold, gem, ornamental rocks, manganese and limestone, and others. Inside it is inserted the Metropolitan Region of Belo

Horizonte which besides the own capital, includes more 33 counties, with a population of 5,4 million inhabitants.

1.4.2 Infrastructure Aspects

The state of Minas Gerais is united by efficient road-railway system to the main three Brazilian ports: Rio de Janeiro, Vitória and Santos. The transports' infrastructure of the state detached by the extensive road network (264.898 km by road, which 19.266 km paved), and for retain 20% of the national railway system. Therefore, Minas Gerais is the main highway and railway intersection of the Country, as the logistic allows a quickly access to the national and international, since there are 5 customs stations in the interior and in the Tancredo Neves International Airport, besides others regional airports with paved tracks.

The main airlines companies of the country have regular flights to the biggest counties from the state of Minas Gerais. Belo Horizonte has two modern airports, being the Pampulha airport, located inside the limits of the city, have focus on the private flight, the "commuter-airlines" and the "flights-to-flights", while the Tancredo Neves International Airport, located in Confins, in the Metropolitan Region, operates with domestic flights of large range and international flights.

CEMIG-S/A is the main electric power company of the State, which supply electricity for 97% in the state. The power plants under the total or partial control by the CEMIG have installed generation capacity by 5.500 MW and

reached around 7.500 MW in 2005. There are four others electric power companies acts in the rest of the state of Minas Gerais.

COPASA is a company responsible for supply treated water to 598 allocations, and serving about 10 million people. In 61 allocations, the company have the concession to manage the collection services and the final destination of sewerage, service giving to 4,5 million clients. The counties that do not have the COPASA service have autonomous service of water and sewerage, as it is the situation of Itabira.

1.5 – ALLOCATION

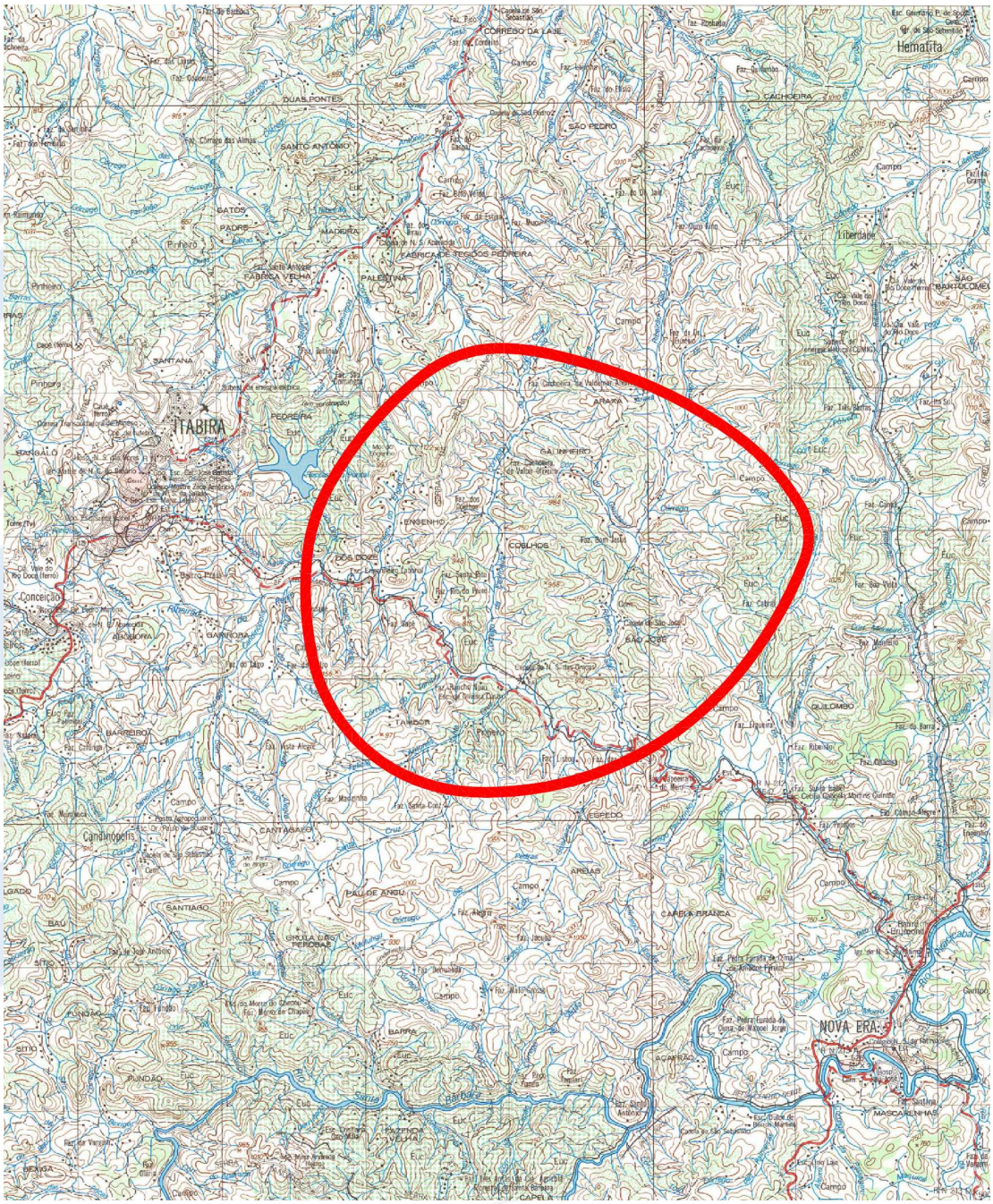

Figure 1 - Allocation (Base – IBGE)

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1.6 – THE COUNTY OF ITABIRA

1.6.1 Characterization

Allocation: CENTRAL

Area: 1254,49 Km2

Altitude:

maximum: 1672 m
place: Alto da Mutuca
minimum: 783 m
place: Foz do Corrego do Simao
Central point of the city: 779,91 m

Temperature:

Average annual:	20,1 C
Maximum average annual:	26,5 C
Minimum average annual:	15,9 C

Average Annual Rainfall: 1372 mm

Relief:

Topography	%
Flat:	10
Wavy:	20
Mountainous:	70

Main Rivers:

RIO DO PEIXE
RIO SANTA BARBARA

Bay: RIO DOCE BAY

Sources: Institute of Applied Geosciences - IGA
Brazilian Institute of Geography and Statistics - IBGE

Boundaries Counties:

SANTA MARIA DE ITABIRA
ITAMBE DO MATO DENTRO
NOVA UNIAO
BOM JESUS DO AMPARO
BELA VISTA DE MINAS
JOAO MONLEVADE
SAO GONCALO DO RIO ABAIXO
NOVA ERA
JACUTINGA

1.6.2 Population

Resident Population
1970,1980,1991,2000,2005

YEARS	URBAN	RURAL	TOTAL
1970	41.199	15.153	56.352

1980	58.685	12.430	71.115
1991	72.954	12.652	85.606
2000	89.357	8.606	97.963
2005(1)			106.289

Source: Brazilian Institute of Geography and Statistics (IBGE)

1.6.3 Historical Registers

In the year of 1720 became the official constitution date of the Itabira Village. Its existence it was, however, already known since 1705, when it was found the alluvium gold and was built the first chapel. The gold was not too much and than the village does not developed in this initial phase. The iron ore, due the existent prohibition by the Portuguese Crown, had its restricted exploitation to produce cookware.

Only in the end of century XVIII, the gold associated with the iron ore of the peaks of Conceição, Itabira and Santana, came to be explored by small mining company. At the beginning of century XIX, Itabira was prospering, making possible the socio-cultural advance of their aristocratic class. From the year of 1808, with the Portuguese Real family arrival to Brazil, and with the consequent release of the iron exploration, emerge than several foundries in Itabira that had started to supply instruments for mining, for agriculture, for domestic use and for small arms.

If for one hand the gold production starts to decline in the middle of this same century, and the incipient siderurgy is affected with the slavery's abolition, the city starts the development of an economy focused to the internal consumption and of a regional supplying. In this period of "internal economy" the city takes advantage on their potentialities: extracts the ore and forge the instruments to their agriculture; weaves the cotton and manufacture fabrics; manufacture harness with leather of their animals.

Two importants accomplishments show the reached advances in the city: The creation of the Agronomic Institute (1881), for the improvement of agri-stockbreeding production in the region, and the inauguration of the telegraphic station (1884).

In the first half of century XX, the city will be target of the international and national conjuncture's influence. Detached the International Geologic Congress of Stockholm, which in 1908; make an announcement the ferriferous potential of Minas Gerais and attracted the interested of several foreign investors. In 1910, the English constituted the Itabira Iron Ore Company Limited, with an intention to guarantee the existent reserves of iron ore and the control of the railway that would be built connecting Minas Gerais to Espírito Santo states.

When the First World War finished, the control of the Itabira Iron was transferred to a group of Europeans and North-Americans investors that do not start to explore the ore for a contractual question with the Brazilian Government. Just in 1942, from the designated "Agreement of Washington", was possible the creation of the Companhia Vale do Rio Doce that triggered the exploration of ore consistently.

The city's profile will change drastically with the implantation of the Companhia Vale do Rio Doce - CVRD. Again the city will deflect your economic axis to the international market economy, reorganizing to accept new inhabitants that arrive seeking for a work opportunity. Public and private educational institutions will be created, up to the higher education.

1.6.4 – Recent History

The 80's was marked by the debate about the necessity to search economic alternatives for the county, as the CVRD starts to act in a stable way in others region of the country. So the relation between the city and CVRD was modified, searching solutions through partnerships. In accord hold between the City Hall, CVRD and the Industrial Districts Companies CDI-MG, occurred the first Industrial District of Itabira.

Some adopted methods from the 90's, period of intensification of the globalized economy and the privatization of CVRD, consolidated the search for alternatives, detached the creation of an Agency of Economic Development Itabira – ADI and the Fund of Economic and Social Development Itabira - FUNDESI, with the input of resources of CVRD and City Hall of Itabira.

Along this, the city finds other vocations for their development, besides those purely industrial. So, they created the Community Foundation of Higher Education of Itabira – FUNCESI, which today has courses in the area of Literature, Mathematics, Geography, History, Business Administration, Accounting, Life Science, Information Systems, Tourism and the Rule of Law.

The tourism is already emerging, since the city as the birthplace of an important poet called Carlos Drummond de Andrade, become an important center of studies of his work. Due that was built the Memorial Carlos Drummond de Andrade, project by architect Oscar Niemeyer. Also was built the

Museum of Territory “Drummondianos Path” where the poems are recorded in the places which he refers in his work.

In another way seeks to increase the eco-tourism, as in Itabira have natural attractives as waterfalls, forests, rapids in their districts Senhora do Carmo and Ipoema, allowing all kinds of tourism ecological exercise as trekking, canoeing, hiking, camping, etc... .

1.6.5 – Urban Infrastructure

Several accomplishments have contributed to make Itabira one of the cities that offer to its residents and visitors a wide option of social facilities for an example the Cultural Center, with its modern theater to 423 seats and a large park of Agri-stockbreeding Exhibitions with capacity and infrastructure to accommodate more of 50,000 among exhibitors, producers and the general community.

In the health aspects, the city has two hospitals (Nossa Senhora das Dores and Carlos Chagas) and a well equipped E.R. , which is reference to the cities around the region, besides a network of clinics for the population’s ambulatory care.

In the total municipal income, of the state of Minas Gerais, Itabira is in 9th place. In relation to the collection tax, is placed in 19th in the statewide.

The electric power that is consumed in the county is supplied by the Power Company of Minas Gerais – CEMIG, which there is a substation with

power of 31 kV. The CVRD keeps another substation with Power of 230KV. The water supply is under responsibility of SAAE- Autonomous Service of Water and Sewer, municipal autarchy that operates with 3 systems in a total of 375 l/s of treated water. In the urban area of the county 95% of the public ways are paved and illuminated.

2 - LOGISTIC AND ACCESSIBILITY

2.1 – HOW TO ARRIVE

Leaving from Belo Horizonte, through BR-381 around 58 km up to the interchange with the road MG-434 and keep going eastbound in the BR-120 going through the south interchange of Itabira in a trajectory around of 26km on this road. From the bridge in front of the Fazenda das Piteiras, follow northbound by the left edge of the Ribeirão São José around 6 km up to the area that located in the Fazenda Bom Jesus, next to the border with the Nova Era County.

2.2–MAIN HIGHWAYS OF ACCESS

The main access routes to the area of the process are made through the BR – 120, MG – 129 and MG-434 besides the vicinal roads in the rural area of Itabira-MG.

2.3 – AIRPORTS

The main airport next to the area of the process is the Tancredo Neves International Airport, located in the Confins County – MG, metropolitan region of Belo Horizonte, in a trajectory of approximately 150 km up to the area. Another important airport present in Belo Horizonte is the Pampulha Airport, which was considered an international airport before the transference of its activities to the Tancredo Neves International Airport. Nowadays Pampulha

operates just the regional flights. This airport is located about 120 km of distance to the area of the process, being its access by the Tancredo Neves International Airport route, through BR-040.

Figure 2 - Partial View of the Tancredo Neves International Airport

3 – DETERMINATION OF RESERVES

3.1 - ACCOMPLISHED RESEARCH WORKS

The research works relative to the Galinheiro Project are already finished, being that the Final Research Report positive was already presented to the DNPM and confirmed, as shows this file the economic viability of the project.

Two products were identified that even ploughed by independent manner are economically viable. They are the granite, to be commercialized as ornamental rock, and the beryl emeralds, present in the ultramafic schists and esteem in function of the associated rock.

In the two cases the deposits had demonstrated an excellent economic performance that classifies them as coal bed.

3.2 – REGIONAL GEOLOGY

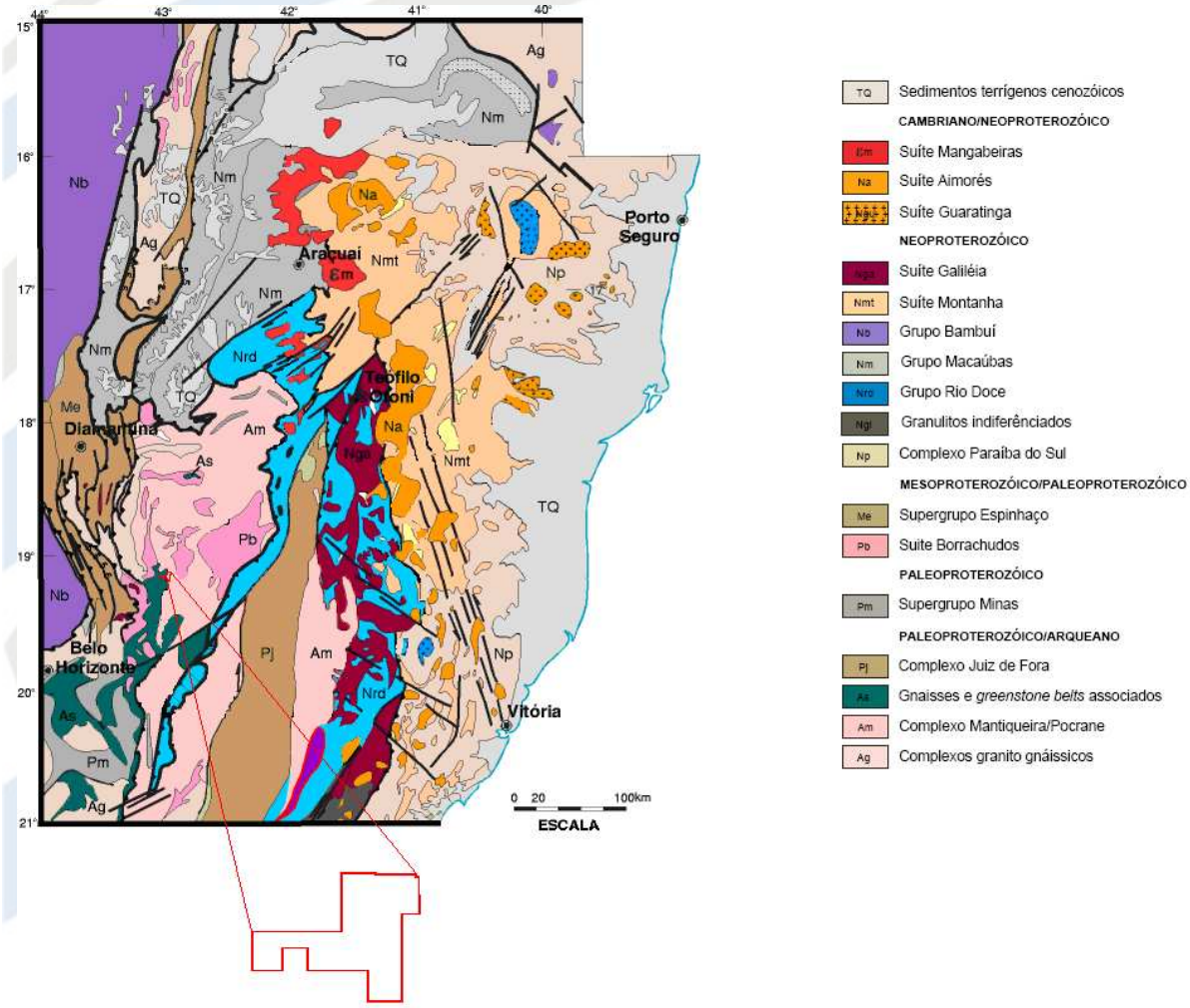

Figure 3 - Regional Geology

In this last decade, the region in esteem have been the target of a many studies (PEDROSA-SOARES *et al.,* 1992a, b, 1998a, b, 2000; PINTO *et al.,* 1997, 1998; NOCE *et al.,* 1999; CUNNINGHAM *et al.,* 1996; NALINI *et al.,* 1997, and

others), with significant progress in the more consistent evolutional models proposition. PINTO *et al.* (1997) revealed several granitic suites in the east region of Minas Gerais. PEDROSA-SOARES *et al.* (2000) showed a detailed reviewed of the orogeny evolutional Araçuaí – West Congo and congregate the granitic rocks in five suites (called G1 to G5), on basis in petrographic, chemistry, geocronological and geotectonic parameters.

The studied region is inserted in the Belt domain of Araçuaí, Brasiliano, constituent of the septentrional portion from the structural province or Mantiqueira geotectonic (ALMEIDA & LITWINSKI, 1984; ALMEIDA & HASUI, 1984; PADILHA *et al.,* 1991). Ancient reworked properties, remnant of the structural province or São Francisco or Mantiqueira geotectonic, are represented by the nucleus of Guanhães, Pocrane and Gouveia. These nucleuses congregate from archaean rocks to paleoproterozoic, distorted in the Transamazonian and Brasiliano events. They are represented by the gneisses TTG, with mafic and ultramafic rocks associated (complex Basal, Mantiqueira, Gouveia and Córrego do Cedro), volcanic-sedimentary sequences greenstone type (Complex Guanhães; age Pb-Pb in zircon of 2573 +/-25Ma, NOCE et al., 1999; Rio das Velhas Supergroup, Rio Paraúna Supergroup and possibly, Riacho dos Machados sequence). Eclogite is described in restricted areas. Paleoproterozoic ferriferous sequences of the Minas Supergroup or correlatives are well displayed in the adjacencies of the Itabira City.

In the superior paleoproterozoic, around of 1,7Ga, started the process of rifting that allow the appearance of granitoid type – A of the Suite Borrachudos and acid volcanic to continental intermediate, these last one identified, in a discontinuous ways, from Conceição do Mato Dentro to the surrounding of Monte

Azul and Mato Verde, next to the boundary with Bahia State. Such fact delimits the origins of the rift Espinhaço opening. DOSSIN et al. (1993) obtained age Pb-Pb of 1729±14Ma to the São Félix Granite and of 1595±10Ma to the Itauninha Granite, called as Suite Borrachudos. The process developed with the Espinhaço Supergroup settlement consolidation in the Mesoproterozoic (post-rift stage).

In the Neoproterozoic was introduced the Belt Araçuaí-West Congo, during the Brasiliano Cycle, with oceanic crust generation (PEDROSA-SOARES *et* al., 1992a, b; 1998b), settlement, metamorphism and distortion. The whole region was reworked, including the Transamazonian and Archaean foundation. This orogeny developed restricted by the São Francisco and Congo Cratons. Have limit south imprecise with the Belt Ribeira (Brasiliano), but is accepted by the PEDROSA-SOARES *et al.* (2000) in the parallel 21 °S, approximately, where its structures, preferentially guided N-S, seems to separated with the tectonic structures of the preference direction NE-SW, features of the Belt Ribeira. In the extreme north of the Belt, along to the boundary of Minas Gerais with Bahia, the tectonic structures deflect to E-W, shaping to the São Francisco Craton outline.

PINTO *et al.* (1997) shared, informally, the Belt Araçuaí between Padre Paraíso and Aimorés in an oriental domain and another occidental. PINTO *et al.* (1998) debated the developed of the Belt Araçuaí partitioned in a external tectonic domain and another internal. The external domain, as conceived by those authors, tacked into São Francisco Craton, forming an arch structure in the Craton periphery. The internal domain occupied the remaining of the territory, going from the Meridian 42°30'W to the Atlantic coast and from the parallel 16°S to parallel 21°S.

The limit between the internal and external domain is represented by the shearing zone of low angle (or contracional), by meridian position, segmented by the calcium-alkaline granitic batholith of high-K (Aimorés Intrusive Suite, G5), in its central portion. The extreme north of this shearing zone get lost inside the peraluminous granites of the G2 and G3 suites, in the valley of the Jequitinhonha River. The mass movements are from the actual littoral to the actual interior in the direction of São Francisco craton and reach the both domains, not affecting the granites of the G4 and G5 suites. This tectonic put the external domain (occidental) over the pre-brasilianos (reworked ancient nucleus of Guanhães, Procrane, Gouveia and domains of the São Francisco Craton represented in the most part by the complex Juiz de Fora, Mantiqueira and Procrane) and the internal domain (oriental) over the external. These compacted movements led to the tectonic disposal of the foundation sequence and its covering, involving the crustal level from the median to the lower of a basian meso to neoproterozoic, with the peak of distortion in the Brasiliano (CUNNINGHAM *et al.,* 1996, amongst others).

This median shearing zone determinates an important discontinuity metamorphic. The metasediments of west and north, next to the São Francisco Craton and representatives of the external domain, are metamorphosed in the green schist to amphibolite facies. The metasediments of east, far from Craton and representatives of the internal domain, show metamorphism in the high amphibolite to granulites facies, with importants granitics fusion S- type (G2 and G3 suites). Peraluminous granites (G4 Suite), cambrian, occur in the external domain, since the region

in north of São José da Safira to the proximity of Novo Cruzeiro and are the source of mineralized pegmatite in tourmaline.

The gravimetric discontinuity of Abre Campo (HARALYl *et al.,* 1985), a probably transamazonian structure that in part, limit property of the Archaean and of the Transamazonian, occupied a meridian position in a high foundation situated between the oriental and occidental extremes of the external domain. It is configured as an extensive zone of shearing with frontals, oblique and elapsing components (PADILHA *et al.,* apud RAPOSO 1991).

The external domain involved the Archaean-Paleoproterozoic foundation, represented in São Francisco and Mantiqueira Province. This foundation is constituted, mainly, by gneisses TTG, with metavolcanicsedimentary sequences associated (in part greenstone type), and by granolithic properties. As for the foundation were introduced supracrustal proterozoic unities. They are represented by elastics metasediments paleo- to neoproterozoic of the Espinhaço Supergroup, deposited in continental environment and of transition (rift stage) and coastal to platformal (post-rift stage).

In the Neoproterozoic occurred a wide sedimentation in the continental, transition and marine environment, sometimes with glaciogenic characteristics, of the Rio Doce and Macaúbas group (represented by schist and aluminous gneisses, in part migmatized, quartzite, calcissilicatic rock, and restricted marble). They present a sedimentary polarity in the east direction, with accumulation of the sequences in the environment of passive continental edge. It is present a polarity

sedimentary in the direction east, with accumulation of the sequences in environment of passive continental edge. (NOCE *et al.,* 1997).

Some lithics register of the Rio Doce Group are similar to associations of the QPC type (quartzite-pelites-carbonate) and suggest deposits of a desert system in a stable region, as a craton, continental edge or the continental side of a retro-arch basin (PEDREIRA & SILVA 1998). The Dom Silvério Group is being considered as an extension of the Rio Doce Group, to south.

Metaluminous Granitoids, pre-to syncollisional, neoproterozoic (Galilea Intrusive Suite, G1; age U-Pb in Zircon of 594+/-6Ma., NALINI JÚNIOR *et al.,* 1997; Pb-Pb in Zircon of 576+/-5Ma., NOCE *et al.,* 1999) and granites S-type, post-tectonics, cambrian (G4 Suite = Mangabeiras Suite, Santa Rosa Granite and correlates granitic veins; ages Pb-Pb in Zircon of 503+/-9Ma., NOCE *et al.,* 1999) have regional distribution in this domain, occurring as dikes, small bodies or batolithics bodies.

The charnockitic/granolithic suite of Caparão shows porphyritic domains that is similar to Aimorés Intrusive Suite (Padre Paraíso Charnockite) and Bela Joana and to "granolithic" of the Valentim Mountain Range (VIEIRA, oral communication, 2000). The accepted age to the granolithic metamorphism of Caparão mountain range rocks is ca. 586Ma (U-Pb in zircon. Another value of 2176+/-30Ma was considered the age of the detrital zircon source; SÕLLNER *et al.,* 1991). The composition is from granodioritic to tonalithic-trondhjemitic, with a chemistry reaction compatible with granite S-type (SEIDENSTICKER & WIEDEMANN, 1992). The metamorphism age is based in a lower intercept and

the paraderivation in a petrochemical diagram of bigger elements. There may be transamazonian granolithics domains and brasilianas charnockitic intrusions in Caparão.

VIEIRA (1997) considered the metasediments surrounding the Caparão Suite as belonging to Paraiba do Sul Complex, with a metavolcanicsedimentary layer comprising an abundance of metamafic-ultramafic bodies represented mainly by pyroxenite, serpentinite, steatite, amphibolite. Similares rocks were described more in the north direction, in this project, some positioned in the Procrane Complex domain, others in the Rio Doce Group domain. Fragments of schistified ultramafic rocks also were found in the region of São José da Safira, during the works of the first stage of this project. BARBOSA *et al.* (1964) referring to amphibolite and talcitos (rock rich in the mineral talc) interpolated in supracrustal rocks of the Middle Rio Doce, nowadays considered of the Rio Doce Group. Metanorthosites associated to the metamafic-ultramafic of Ipanema showed ages Sm-Nd of 1030+/-67Ma (age of crystallization) and age U-PB of 630+/-3Ma (age of metamorphism), according to ANGELI *et al.* (2000). These rocks can be correlations with the remains of the oceanic rocks association described by PEDROSA-SOARES *et al.* (1998b, 2000), in Ribeirão da Folha and proximities.

Brasiliano pegmatite (manufacturers of gem and collection pieces) are plentiful on this external domain, in the schist of the São Tomé Formation (Rio Doce Group), in porphyritic granites of the Aimorés Intrusive Suite (G5 Suite= Caladão Granite, in the limit between the two domains), in the granitoid of the Galilea Suite (G1 Suite) and associates to Santa Rosa Granite (G4 Suite).

The internal domain is represented by metasediments clastic-chemical marine-platforms (kinzigitic, quartzite, marble and calcissilicatic rock) metamorphosed in the amphibolite to granolith facies (Kinzigitic Gneissic Complex or Jequitinhonha; Paraíba do Sul Complex); Tonalithic gneisse to hypersthene (Enderbite Mangalô), peraluminous leucogranites syn- to tarditectonic (G4 Suite= Mountain Suite and Almenara, age Pb-Pb in zircon of the Ataléia 591+/-4Ma; NOCE *et al.,* 1999); Calcium-alkaline granites of high-K, tardi- to post tectonic (G5 Suite= Aimorés Intrusive Suite, age Pb-Pb in zircon of 519+/-2Ma; NOCE *et al.,* 1999). These supracrustal sequences represent platformal marine deposits.

With the advance of the works, is possible that new properties division (domains) be established. In a first moment it could be suppose an occidental property formed by the Macaúbas Group (Salinas, Capelinha and others formations), Dom Silvério Group (at present redefined to Rio Doce) and granites of G4 Suite; an oriental property formed by the Kinzigitic Gneissic, Jequitinhonha; Paraíba do Sul Complex and granites of the G2 and G3 Suites and, in part G5; and a central property formed by the Rio Doce Group and Galilea Intrusive Suite (G1 Suite). These properties may have relation with the Araçuaí and Rio Doce orogenisis, brasilianas (see PEDROSA-SOARES *et al.,* 2000; CAMPOS NETO & FIGUEIREDO, 1995), with evolutions in distinguished times.

An important tectonic structure, of direction NNE, is appeared by the valley of the Rio Itambacuri. Its continuity to southwest is suggested by the alignment of the Rio Doce (passing by the region of the Rio Doce Park) between the cities of Governador Valadares and Ipatinga, continuing in this

direction up to the Ferriferous Quadrilateral, where seem to finish in the Fundão fault. This structure cut neoproterozoic rocks to archaean, introducing itself covered in a wide stretches by quaternary deposits. Show evidences of horizontal and oblique movements along to its extension, connecting or truncation shearing zones of low angle. Neotectonics reactivations can be present in the region of the Rio Doce lakes, conforming hemigraben to trace NNE and sinking of the west block.

A breakable tectonic affected all the lithics unities of the referred domains and along to some of these structures positioned basic dikes, possibly of Cretaceous/Jurassic.

Cenozoic Deposits are represented, mainly, by the sedimentary cover of the Barreiras Group (Tertiary), sedimentary terrace, mainly in the Rio Doce valley (Pleistocene?) and alluvial deposits along to the big rivers.

3.3 – LOCAL GEOLOGY

The area has a geology characterized by a metavolcanicsedimentary sequences, associated to a granitic event belong to the “Borrachudos Suite” (Annex III: Geologic Map). The pegmatite are located, mainly, next to the contact of the granit with the slopes gneisses from the archaen supracrustal sequence. Others pegmatitics bodies, that occur far from this zone, are poor in gemstones, do not forming a coal bed. In the Layers Itabira - Nova Era is noticed a large incidence of phlogopite schist (metavolcanic) that turns the area favourable to the emeralds mining. It is verified a large incidence of volcanism, being the sedimentary portion subordinated, that turns the frequency of a constant emeralds mining.

The bodies thickness may vary from < 0,5m to 2,0m, in general. They have a lenticular form, showing variations in the thickness, frequently forming pockets. They are pegmatite of the zonado type, occurring also (in a small quantity) the homogeneous pegmatite. The ultramafics schist (biotite/phlogopite) carriers of emerald results of a chemistry interaction between the pegmatoid fluid (carriers of beryl) of the adjacent granites and the metaultramafics rocks of the volcanic sedimentary sequence (carriers of chromium, iron and vanadium).

AGE		LITHOLOGY
QUATERNARY	Holocene	Superficial Formation **QHa** Alluvium **QHc** Colluvium
PROTEROZOIC	Paleoproterozoic	Borrachudos Suite **GT**

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Belo Horizonte - MG - Brasil

ARCHAEAN	Rio das Velhas Supergroup **ARVi** Undivided Mantiqueira Complex **Am**

Table 1 - Stratigraphic Column

3.3.1 – MANTIQUEIRA COMPLEX

The Mantiqueira designation was firstly used for BARBOSA (1954), in the series category, to the gneissic rock of the Mantiqueira Mountain Range. EBERT (1956) positioned these rocks in the Undivided Archaean, abandoned the denomination Mantiqueira Series. TROUW *et al.* (1986) retaken in the group category, the Mantiqueira term to congregate gneisses with amphibolite intercalation, which occur in the homonym Mountain Range.

The Mantiqueira Complex term is here used to denominate the gneissic rocks from the emphasized region. They are essentially ortogneisses of the tonalite-granodiorite-granite type, unified with the denominated rocks in the literature as Basal Complex in the Guanhães region (GROSSI SAD *et al.,* 1990a), Marilac (RIBEIRO, 1997) and Santa Maria do Suaçuí (SILVA, 1997) due to its compositional and structural similarities.

The Mantiqueira Complex constituted the ortoderivated gneissic foundation of gray color, showing compositional layering where its alternates the felsic bands with mafics bands with predominance of the biotite. The bands have in general,

thickness millimetric to centimetric. Metabasics and Pegmatite bodies are interpolated to the gneisses, normally concordant with the gneissic layering.

These rocks shows a granoblastic and lepidoblastic texture, granulation from thin (= 0,5mm) to middle (= 1,0 to 3,5mm), with accentuated orientation of the mafics minerals. Granular hipidiomorphic Texture is occasionally preserved. The melanosome has tonalithic to granodioritic, meanwhile the leucosome show the granitic composition. The essential constituent are plagioclase (15-40%), K-feldspar (0-45%) and quartz (15-40%), as varietal to biotite (2-15%), more frequently green, accompanied by variable quantities of hornblende (0-20%), White mica (0-10%) and garnet (0-5%). The accessories minerals are apatite, titanite, allanite, zircon, xenotime, rutile and opaques, occassionally tourmaline.

The plagioclase is predominantly subhedral, intersecting twin or not according to albite, albite/Carlsbad and, enventually albite/pericline. Pertites, edges of delayed albitization, antipertites and mimerquitas (quartz+feldspar) are observed frequently. The migmatics shows ptygmatics folds and the paleosome and neosome separation. Occuring restricted to a few outcrop. These migmatization are associated to the Transamazonian Event, as, the brasiliana distorted is penetrative in these rocks. The Brazilian actuation will be also responsable, by the anatetic phenomenon, of lower expression, that segregating mafics and felsics portions. Its alternated from the granitics to tonalithics portions.

Associated to these ortogneisses occur amphibolites and metapyroxenite (rare). The **amphibolites** have nematoblastic or thin

granoblastic texture, being compound essentially by hornblende, plagioclase and quartz, having as mineral varietal to biotite, and sometimes, the clinopyroxene. The usual accessories minerals in these rocks are apatite, zircon, opaque and epidote.

3.3.2 RIO DAS VELHAS SUPERGROUP

Supracrustal metavolcanicsedimentary are represented by schists with intercalations of amphibolite, quartzite, and ferruginous quartzite and ferriferous formation. GROSSI-SAD *et al.* (1990) had called this set of Guanhães Group and shared it in three formations: *i) Inferior,* with metavolcanic predominance. *ii) Middle,* with chemical and elastic metasediments. *iii) Superior,* paragneisses with discrete quartzite intercalations, ferriferous formation and amphibolite.

The designation Rio das Velhas Supergroup to the supracrustal is due to the petrographic similarities between the rocks of the Guanhães Group by GROSSI-SAD *et al.,* 1990a, and those described in the Ferriferous Quadrilateral by the DORR *et al.* (1957) and in the Project Rio das Velhas executed by the convention DNPM/CPRM (ZUCCHETTI & BALTAZAR, 1998). Still considering the physics continuity observed during the mapping of the Itabira (PADILHA & VIEIRA, 1995) and Coronel Fabriciano (SILVA, 2000) Leaf. The exception is made by the metamorphism, which in the focused area, reached the amphibolite facies.

The Supergroup Rio das Velhas is compound by ferriferous, quartzite, schist and paragneisses formation. The ferriferous formation has a friable and thick grain

aspect, intercalating it to the quartzose level to levels with specularite and magnetite. The schists are compound by quartz, biotite, sillimanite, white mica and opaques, while the **paragneisses** occur extremely desintegrated, alternating silt-sandy levels to sandy levels, about the Mantiqueira Complex.

3.3.3 Borrachudos Suite

DORR & BARBOSA (1963) originally called *Borrachudos Granite* the Granitoids from middle to thick granulation, rich in potassium feldspar, that occur along to the homonym creek, in Itabira county. They were interpreted by them as generated in late orogenetic stages, being post-tectonic intrusive rocks, younger than the pre-cambrian metasediments of Minas Supergroup.

REEVES (1966) observed graded contacts of these granitoids with gneisses, that considered as paragneisses belong to the Piracicaba Group by Minas Supergroup, during its investigation in João Monlevade County, where described a continuation to the granitoid south by Mina Belmont. The author considered such syn-metamorphic metasomatic rocks, resultants of a regional metamorphism by high degree.

SIMMONS (1968), in agreement with the ideas of DORR & BARBOSA (1963), interpreted such rocks as intrusives and post-tectonic, during the geologic mapping of the region by Barão de Cocais, where occurs the body of São Gonçalo do Rio Abaixo.

HERZ (1970) considered about some petrogenetical aspects of these rocks and concluded that the Petí and Itabira bodies will be the igneous co-magmatics rocks, of granitic to adamellitic composition, intrusive and post-Minas Supergroup. The conditions of proposal crystallization are not conclusive and actually are contradictory. On the basis in the analyses of the bigger elements in the alkaline feldspar and in the mesoperthitic nature considered higher temperatures, of hiper-solvus granites. The other side, considering the small elements on this feldspar, inferred lower temperatures of crystallization.

CHEMALE Jr. (1987), from petrographic and petrochemical studies of the Itabira Body, characterized these rocks as originated by a peralkaline magma, denominated such rocks of Borrachudo Gneisse pointing out the deformation and the metamorphism attributed to the orogeny of Minas Supergroup.

MACHADO *et al.* (1989) and DUSSIN *et al.* (1993) showed results U/Pb and Pb/Pb in zircon indicating between 1715 and 1730Ma for these rocks.

GROSSI SAD *et al.* (1990), due to petrographic and chemical similarities, denominated Borrachudos Suite to set of plutonite positioned to the east of Espinhaço Mountain Range and associates geographically to Basal Complex and to Guanhães Group and more to the east, next to Rio Doce gutter, called Plutonite Açucena (that occurs in Ipatinga Leaf).

The following bodies would make part of the Borrachudos Suite: ***Itabira*** (Itabira and Conceição do Mato Dentro Leaf); ***Petí*** (Itabira Leaf); ***Morro do Urubu*** (Guanhães Leaf); ***Cansação*** (Rio Vermelho and São Sebastião do Maranhão Leaf);

Senhora do Porto (Serro and Conceição do Mato Dentro Leaf); **São Félix** (Serro Leaf) and **Açucena** (Guanhães, Marilac, Ipatinga and Dom Cavati Leaf). The mapping accomplished in the East Project reviewed that there is not physics continuity from the Açucena body up to the Conceição do Mato Dentro Leaf, as suggested the Espinhaço Project. (GROSSI SAD, 1993).

SCHORSCHER (1992) interpreted the Borrachudos granitoids as orogenetic, syntectonics, formed in the sialic TTG environment, along to the brittle-ductile shearing zone, deep and of regional extension, developed in a final evolution stage of greenstone belt archaean Rio das Velhas. Such author based the relative age of these granitoids in the relations of the São Gonçalo do Rio Abaixo body with the metasediments of Nova Lima Group; of Itabira granitoids with retrometamorphic intrusive tonalites; in the metamorphic characteristics and in the regional influence of granitoids as high structural and foothills in the sedimentary and structural evolution of the Minas and Espinhaço Supergroup. Still according to SCHORSCHER (1992), the metamorphic process and metasomatics, strongly allochemical, obliterated the propriety of the pre-existent rocks (mylonite-gneisse, mylonite-schist) and conferred characteristics of alkaline-feldspar granite, A-type or still peralkaline.

DUSSIN, T. (1994), DUSSIN, I. (1994), DUSSIN & DUSSIN (1995) and DUSSIN *et al.,* (1996) attributed a magmatism of anorogenic character to the Borrachudos Suite, related to the distension tectonic which would have affected the region in Mesoproterozoic and would have culminated with the installation of the Espinhaço rift.

DUSSIN, T. (1994) described the granitoids not too much deformated, with preserved magmatic foliation.

FERNANDES *et al.* (1994, 1995 e 1996), analyzing the rocks of the Dores de Guanhães region, where such authors denominated Dores de Guanhães embankment, belong to the Borrachudos Suite, described these rocks as homogeneous and showing magmatic foliation, in agreement with model of DUSSIN, T. (1994). FERNANDES *et al.* (1996) showed some estimates about the crystallization condition and speculated that these rocks would have crystallized at temperatures between 873° and 772°C.

CHEMALE Jr. (1998) showed data U-Pb of 1670±32Ma in zircon. The standard of the Rare-Earth Elements (REE) is enriched in light REE, depleted in heavy ETR and show significant negative anomaly of Eu.

FERNANDES (1999) recognized the brasiliana deformation in the Dores de Guanhães region and showed data U-Pb in tinatine indicating an age about 507Ma.

The Açucena granitic embankment (Borrachudo) occupies the northeast portion of Ipatinga Leaf and its extended to the Dom Cavati Leaf, to the east, Guanhães, to the north and Coronel Fabriciano, to the south, beyond the islands arround the gneisses of Mantiqueira Complex, Itabira Leaf. Morphologically, constitutes a mountains area sufficiently dissected, with conditioned valleys by the structuration, with emphasize to the forms of Sugarloaf Mountain (in Portuguese called Pão-de-açúcar).

These Metagranitoids have from middle to thick granulation, shows the gray color and penetrative deformation, not treating of the edge deformation, as internal outcrops also its show deformed. A saliented foliation by the biotite is characteristic. The rock shows from thin to very thick granulation, showing biotite pockets that produce a spotted aspect. The petrographic analysis does not allow an evident distinction between the gneisses of the Mantiqueira Complex and the Borrachudos Granites. These last one is distinguished essentially for being less deformed (without layering, however very guided and showing ribbons of quartz) and to preserve hypidiomorphic or allotriomorphic granular texture. The modal composition is too similar to the leucosome gneisses.

3.3.4 Superficial Formation

3.3.4.1 Colluvium

Inconsolidated materials with granulometry varying of thin up to boulder. Tend to developed on the average to the low slope and, sometimes, its interdigitated with the alluvial deposits in the low slope.

3.3.4.2 Alluvium

The alluvial deposits are found in the most draining of the studied area. They are compound of gravel, sand and glay. The sand and silts are clayey, nut-brown, organic, in chart and lenticular layers, deposited in a meandering fluvial environment. They are preserved in the low terrace and floodplain of the current fluvial course. They shows age which certified its sub-actual origin,

showing, at least in parts, evidences of the anthropic action, constituting technogenic deposits.

3.4 - RESERVES AND GRADES

The accomplished research works enabled the blockade of the reserves for the Ornamental Rock (Granitic Gneisse) and Emeralds. It was made a geochemical campaign through of Manual auger and manhole. Some pits were leased in a strategic place to verification of the several lithologies and its contact relation. Galleries of research had been opened in the defined aim to the emeralds mining and in pegmatitics bodies. Later was accomplished a boring campaign with a borehole sounding machine MACH 700, executing a total of 249,60m. In the most promising aims as far as the ornamental rock as far as the emerald were accomplished specific sampling and tests.

3.4.1 – Reserves of Ultramafic Schists

The pegmatite body is mineralized with quartz, white feldspar (plagioclase), green marine water, and white beryl and is inserted in layers of several thicknesses by ultramafic schists, with predominance of biotite, from reddish purple to black colors, with presence of emeralds by soft to moderate color, highly crystallized.

The occurrence area of the Volcanic-Sedimentary Sequence found in this project, have respectively 400m of length by approximately 300 meters of width and the other have 100 meters of length by approximately 300 meters of width. From the results of the galleries, trench and orificies of borehole, it can be

considered an average thickness of 1, 00 meter by schists metaultramafics carriers of emeralds; **totalizing 150.000 cubic meters of metaultramafics schists.**

3.4.2 – Reserves of Granite

Based on the accomplished mapping, it was determined that 03 emerging embankment denominated M1, M2 and M3, are sufficient for the exploitation project. So, it was developed calculations of reserves based on the standardized geometrical figures (rectangle), in order that in the chosen sites, the gradient of the embankment slope is quite homogeneous and constant.

There were not also observed planar or linear elements of penetrative character, non-existing fractures families. There was not also found weathering modification of big range, its summarizing only a small superficial modification in the mafics minerals, more sensitive to the chemical decomposition.

The measured total volume was for the M1 blocks and M2 was of 144.900 cubical meters, already considering a factor of exclusion of 30% in function of the modified rocks from the top.

Due to the satisfactory volume of the two first blocks, the M3 block was not cubed, being considered only as an occurrence, for effect of a viability evaluation of this project, that esteem have a lifetime of 20 years only with the blocks M1 and M2.

4 – ECONOMIC VIABILITY OF THE PROJECT

4.1 – ORNAMENTAL ROCK

The rocks' quality evaluation to the application as coating in the building industry, requires from a technical point of view the consideration of two mainly characteristics: the basic and mechanical properties suitable for its use and the pleasant decorative aspect, that means the effect that the coating will produce in the environment where it will be placed, as for example: external/internal coating, floors, funereal or religious art, washbasin, rest room, etc... .

Therefore, the commercial qualification is established through the material aesthetic characteristics, emphasizing the chromatic standard, design, texture and grain. In case of the present coal bed, the aspect of the polished and finished sample, demonstrated to locate in pattern of light gray color, with variable design in thin gray and white stripes, adjusting it to a type of coating of smooth aspect, without large chromatic gradients, and probably will have a wide acceptance in the building sector.

The enterprise feasibility analysis was developed with the objective to determinate the return internal rate of the investment. So that were prepared various estimates of income and costs, and from these ones were prepared projections of results' demonstrative and cash flow, determining finally the return internal rate of the generated cash flow.

As it can observe in the following described items in a compact way, it can affirm that the project is completely feasible. The consumer market is composed in its majority by exportation of blocks to Europe and the United States, and use the domestic market in civil works of small, mid and large range, where expected that has a consumption about almost 100% of the production. As for the commercialization cost will be expected an increase of 20% over the total cost. It is accepted in the beginning with comparative base in the commercialization of similar material, found in the Espirito Santo State, and in some places in North of Minas Gerais, that the sales price can be stipulate at US$270.27 / m3.

To the blocks' extraction, it is foreseen the use of the following consumables materials:

- Power: 440KW
- Water: 60m3 / hour
- Potable Water: 56m3 / month

To the blocks' production, it is foreseen:

- Scheduled work period: 1
- Esteem operational output: 80%
- Production: 600m3 / month or 25m3 / day or 3,10 m3 / hour
- Annual production: 600m3 x 12 = 7.200m3
- Monthly Income : 600m3 x US$ 270,27 = US$ 162,162.16

The managerial and administrative structure will be composed of the following professionals:

- Project managing
- Mining engineer
- Commercial technician adviser
- Production and marketing managing
- Management assistant

- Production official representative: quarry and maintenance

They are foreseen, the following indirect costs:

- Production: US$48.81 /m3
- Management: US$1.41 / m3
- Global: US$50.22 / m3 + 20% = US$60.26 / m3

As for the workforce, it will have the following professionals:

- College Student: 1
- Specialist/technician: 2
- Qualified: 2
- Basic: 3
- Specialized: 22
- Non-qualified: 16
- TOTAL: 46
- Cost: 21,72% x US$60.26 / m3= US$13.09 / m3

The project implantation cost, it will expected to be the order of US$439,891.89 including civil works, equipment purchase, and operational expenses.

The cost of production then foreseen is of US$73.54/$m^3$, importing that way the order of 27.21% of the obtained income. The amortization period will be 2.5 years.

4.2 – GEMSTONES (EMERALDS)

The analysis results of the exploitation economic feasibility are based on the obtained data along to futures consumers as in the national market as in the international as well as emeralds producers in the region. The Mineral Economics Division of the 3rd District of DNPM (MG) helped with data on emeralds production and consumer market in Brazil.

Worldwide, the occurrences of emeralds are known in Brazil, Colombia, Zimbabwe, Madagascar, Tanzania, Zambia, Kenya, India, Russia, Austria, Sweden and Australia. In Brazil the production of emeralds is proceeding from Minas Gerais State, Goiás and Bahia. The production of emeralds in Minas Gerais is proceeding of the Belmont Gemas Ltda. Mine, Piteiras Mining Ltda and from the placer mining area of Capoeirana in Itabira and Nova Era Counties.

In Goiás and Bahia the productions come from the placer mining exploitation located in Campos Verdes and Santa Terezinha Counties (Góias) and Socotó and Carnaíba (Bahia).

Executing the Mines of Belmont and Piteiras, all the current production of emeralds in Brazil is proceeding from the placer mining exploitation, which production capacity is difficult to control.

According to CBPM (Baiana Company of Mineral Research) the production of emeralds in the region of Carnaíba-Ba in the year of 2000,

relieved a total of “US$ 15.000.000,00” of esteemed sale of raw emeralds. Do not have any reliable information about the total of the produced emeralds.

After verbal research along with emeralds’ buyers in the national market, we conclude that the production proceed from placer mining areas are fallen in last years, basically in function of the technical difficulties to the production.

The raw emeralds’ commercialization as in the national market as in the international, in which India stands out, does not present any difficulty. Since it has been a continuous and regular production is possible to close contracts of commercialization including with advancement of sales, aiming to the financing of projects of mining and processing.

To the emeralds in the region of the matter area from this report the value per gram of raw emeralds vary from US$ 10.00 for emeralds classified as weak to US$ 100.00 for mid emeralds and US$ 200.00 for the extras. Exceptionally the gram’s price of the extra exemplar can reach $ 600.00.

By the investment and income future plans it’s intend to work in the beginning with an average production of 1.000 tpm (tons per month) by raw ore during the 1st year of the exploitation and after this period, with the consolidation of the exploitation plan, the production will be of 2.000 tpm (tons per month).

Based on only the regional historical content, that turns around of 5,71 g/tons and, with obtained data along with the current producers, about of 5% of

the production will be considered as extras emeralds and 10% as mid emeralds. Of the produced total, 20% will be lost during the cleaning process and the remaining 65% are classified as weak emeralds.

We will have the following productions:

	In the month	In the year
Total of Raw Emeralds	5.710g	68.520g
Total of Extras Emeralds (5%)	285g	3.420g
Total of Mid Emeralds (10%)	571g	6.852g
Total of Weak Emeralds (65%)	3.711g	44.532g
Total of Lost Emeralds (20%)	1.142g	13.704g

In the following years these values will be the duplicated.

The project will have the administrative and commercial management with headquarters in Itabira or Belo Horizonte and a local operational management. The workforce will be recruited in the own region and will be given specific training course to qualify the several professionals in the specific areas of the mine to the emeralds' production. A special attention will be given to the patrimonial security of the project.

As for the exploitation phase, based on relatively on the small raw ore monthly production, investment in exploitation and environments projects, equipments to the exploitation, in the beneficiation and the initial development of the exploitation should be around of US$ 540,500.00.

Considering (for the economic analysis) that the underground exploitation cost is always bigger than the open-cast mine (in a same production scale) we can esteem that the production and beneficiation cost, always based on the raw ore production will be:

	Unit Costs	Annual Total Cost
Cost of the Raw Ore	US$ 18.92/t	US$ 227,027.03
Cost of Processing	US$ 13.51/t	US$ 162,162.16
Cost of Commercialization	US$ 5.41/t	US$ 64,864.86
Production Total Cost		US$ 454,054.05

For the first year we will have a production of 12.000 tons and according to the following production data:

	Sale Esteemed Price	Income of the Year
Extras Emeralds: 3.420g	US$ 324.32/g	US$ 1,109,189.19
Mid Emeralds: 6.852g	US$ 162.16/g	US$ 1,111,135.14
Weak Emeralds: 44.532g	US$ 1.62/g	US$ 72,199.46
Income Total Value		US$ 2,292,523.78

Operational Profit in the first year: US$ 1,838,469.73

For the following years it is planned the double of the production and consequently the double of the operational profit above per year, that means, **US$ 3,676,939.46**.

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