A GRAVITY STUDY OF THE PARAMIRIM GRANITE, BAHIA STATE, BRAZIL

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ABSTRACT A large negative Bouguer anomaly of -50 mGal amplitude covering an area of 190 km (NNW-SSE) x 60 km dominates the central part of the northern São Francisco Craton (Bahia State, Brazil). This major gravity feature, which is not obviously related to any exposed causative body, is centrally located over the Archean Paramirim complex but also extends over most of the adjacent Middle Proterozoic Espinhaço fold belt to the west and the Archean Lagoa Real region to the south. A deep seated source of the anomaly such as an abnormal thickening of the crust can be ruled out by estimates of the maximum possible depth to the anomalous gravitating body. The anomaly is attached to mainly unexposed granites and this interpretation is reinforced by the widespread presence of granites in the exposed gneissic-migmatitic basement of the Paramirim complex. Two-dimensional modelling of the granite yields an estimated thickness of 13 km assuming a density contrast of -0.10 g.cm^{-3} or 8 km for a density contrast of -0.15 g.cm^{-3} . The sides of the granite appear to slope outwards. Lack of detailed geological information make it impossible to date the intrusion of this postulated granitic batholith with certainty but the structural relationships of the modelled granite suggest it postdates the Middle Proterozoic Espinhaço orogeny.

RESUMO ESTUDO GRAVIMÉTRICO DO GRANITO DO VALE DO PARAMIRIM, BAHIA, BRASIL. Uma anomalia Bouguer de amplitude -50 mGal, que cobre uma área de 190 km (NNW-SSE) x 60 km, domina a parte norte do Cráton do São Francisco (Bahia). Esta feição gravimétrica, que não apresenta uma correlação óbvia com a geologia local, está localizada sobre o complexo arqueano do Paramirim, estendendo-se por sobre o Cinturão de Dobramentos do Espinhaço a oeste e para a região de Lagoa Real a sul. Estimativas da máxima profundidade do corpo anômalo limitam a profundidade da fonte da anomalia à crosta superior. A anomalia, muito provavelmente está associada a granitos não-aflorantes e esta interpretação é reforçada pela presença generalizada de granitos no embasamento gnáissico-migmatítico do Complexo Paramirim. A modelagem gravimétrica bidimensional do granito fornece estimativas da espessura de 13 km para um contraste de densidade de $-0,10 \text{ g cm}^{-3}$ ou de 8 km se o contraste de densidade for $-0,15 \text{ g cm}^{-3}$. Os lados do granito parecem divergir com a profundidade. A falta de informação geológica de detalhe não permite datar com certeza a intrusão do postulado granito batolítico, mas as relações estruturais do granito modelado sugerem que este é mais jovem que a orogênese Espinhaço, do Proterozóico Médio.

INTRODUCTION The regional gravity survey carried out by Gomes & Motta (1978) set up 2,084 stations over the Precambrian terrain of the northern São Francisco Craton (Bahia State, Brazil). The Bouguer anomaly map which resulted from this survey is shown in figure 1. One of the most striking gravity features is an extensive and large amplitude negative anomaly, situated between 42° - 43° W and 12° - 14° S, over the Middle Proterozoic Espinhaço Fold System (Inda & Barbosa 1978). The amplitude of this anomaly is about -50 mGal and it was initially suggested by Gomes & Motta (1978) that it could be caused either by a local overthickening of the crust or a large granitic intrusion. This negative Bouguer anomaly occurs within an area of highly controversial geological history. The last major tectonic event is Middle Proterozoic (Sá *et al.* 1976a). However, due to a large scatter of late Upper Proterozoic to early Cambrian radiometric K/Ar ages, it has also been suggested that thermal events associated with the Brasiliano orogeny (ca. 500 Ma) may have affected this region.

Large local negative gravity anomalies with steep marginal gradients are generally ascribed to low density granites or sedimentary basins. However, in the present case, there is no obvious geological indication of the possible source of the observed negative gravity anomaly although the exposed Precambrian metamorphic rocks rule out a sedimentary basin. The centre of the anomaly is situated along the eastern border of the Espinhaço fold belt extending eastwards towards the centre of the Paramirim granitic-gneissic complex. By combining the available geological information, aeromagnetic, data and density measurements together with quantitative technique of gravity interpretation such as the maximum depth rule of gravitating bodies (Bott & Smith 1958), the source of the negative anomaly has been investigated. It will

be shown that the most likely source of this large and high amplitude negative anomaly is low density granite. In spite of the ambiguity of the gravity method, it is possible to obtain significant structural information about granitic bodies from their gravity anomalies (Bott & Smithson 1967). In the present study, the subsurface shape of the granite obtained from the two-dimensional gravity modelling provides, to a first approximation, the structural relationship between the emplaced granite and the deformation of the fold belt.

BOUGUER ANOMALY MAP A more detailed Bouguer anomaly map, together with a simplified geological map of the Espinhaço fold system, is shown in figure 2. The distribution of the gravity stations within this area is presented in figure 3. The survey comprises 564 gravity stations: 207 are located at bench marks, 56 had the altitude determined by using barometers and the altitudes of the remaining 301 stations were obtained from contours on the 1:100,000 and 1:250,000 scale topographic maps. A Bouguer anomaly map of Bahia State has previously been published (Gomes & Motta 1978, Motta *et al.* 1981) using a density of 2.60 g cm^{-3} , but as measurements of density indicate this is too low, the Bouguer anomalies have been recomputed in this work using a Bouguer density of 2.67 g cm^{-3} . The gravity values are referenced to the International Gravity System Network (1971). The latitude correction was carried out using the 1967 International Gravity Formula. In regions of rough topography, terrain corrections calculated by Motta *et al.* (*op. cit.*) for terrain out to 15 km have been used. The maximum error in the combined free-air and Bouguer corrections is about $\pm 6 \text{ mGal}$, which is mainly ascribed to the uncertainty in the altitude obtained from contours on the 1:250,000 scale topographic map.

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Figure 1 - Bouguer anomaly map of Bahia State (Brazil) which includes the northern São Francisco Craton based on 4554 gravity stations in which 2084 stations were obtained over the Precambrian terrain by Gomes & Motta (1978) and the remaining 2470 stations, which are situated between 38-39°W and 9-13°S, were provided by Petrobrás. Gravity values are referred to the IGSN 1971, International Gravity Formula 1967, Bouguer density 2.67 g cm^{-3} . The contour interval is 20 mGal. The study area and the interpreted profiles are shown.

Figura 1 - Mapa de anomalias Bouguer do Estado da Bahia que inclui a parte norte do Cráton São Francisco. O mapa é baseado em 4554 estações gravimétricas das quais 2084 foram obtidas sobre o terreno Precambriano por Gomes & Motta (1978) e as restantes 2470 estações, situadas entre 38-39°W e 9-13°S, foram fornecidas pela Petrobrás. Os valores da gravidade estão referidos ao IGSN 71, Fórmula da Gravidade Internacional 1967 e densidade Bouguer $2,67 \text{ g cm}^{-3}$, intervalo de contorno de 20 mGal. São mostrados também, a área do presente estudo e os perfis interpretados.

The large negative Bouguer anomaly trends NNW and covers an area of approximately 60 km (ENE-WSW) by 190 km (NNW-SSE). The amplitude of the anomaly ranges from -40 to -60 mGal and its main axis parallels the Espinhaço fold belt. The anomaly has steep marginal gradients reaching at least 2.5 mGal km^{-1} . The minimum of the anomaly lies along the western side of the Paramirim complex bordering the metasediments of the Espinhaço fold belt. Near latitude 13.5°S, the minimum of the anomaly is shifted towards the centre of the Paramirim complex. To the north, the anomaly terminates at Oliveira dos Brejinhos city. The south end has a gentle gradient and it extends towards the Gavião block. The eastern limit lies at the contact between the Paramirim complex and the folded Middle Proterozoic Chapada Diamantina metasediments. On this side the occurrence of a positive anomaly locally disturbs the NNW trending gradient. The western limit coincides with a major NNW normal fault which extends continuously along the entire western side of the Espinhaço fold belt.

GEOLOGY OF THE ESPINHAÇO FOLD SYSTEM

The Espinhaço fold system (Inda & Barbosa 1978) can be divided into six sub-regions (Fig. 2). The Archean sub-regions include the Gavião, Guanambi, and Paramirim complexes and the Lagoa Real region. These terrains were

also affected by Lower and Middle Proterozoic events, mostly igneous intrusion. In the Middle Proterozoic, intracratonic tectonic events formed the Espinhaço fold belt and the Diamantina tableland.

The basement of the Gavião block is composed of Archean gneisses, migmatites, and plutonic rocks (granodiorites, monzonites, and syenites). Volcanic-sedimentary complexes are extensively found in this region (Mascarenhas 1979). High grade metamorphism characterizes the migmatites and gneisses of this region which was affected by the Transamazônico orogenic cycle (2.2-1.8 Ga). The structural pattern of the Gavião block is very complex, with overprints of several deformation phases, the youngest so far observed being Lower Proterozoic. The same age pattern is observed in the Guanambi complex. This area of exposed Archean basement is basically composed of gneisses and migmatites of granulite and amphibolite facies. Migmatites of intermediate composition are the dominant lithology and these display a complex structural pattern. The last major metamorphic and tectonic event in the region occurred in the Archean at 2.6 Ga (Cordani 1973).

The Archean Paramirim complex is situated between the Chapada Diamantina and the Espinhaço fold belt. According to Sá *et al.* (1976a), the Paramirim complex is composed of gneisses and migmatites of granodioritic and tonalitic composition which are dated at 2.6 Ga. The metamorphism of high amphibolite facies is also Archean. Intrusive granitic bodies are very common in the complex. The structural pattern of this complex shows an apparent overprint of at least two deformational phases. The older (Archean) deformation is shown in the folded banded gneisses and migmatites. The predominantly isoclinal folds do not present any dominant orientation. The younger (Middle Proterozoic?) deformation, which trends NNW, is extensively observed in the complex. Only the K-rich granites south of latitude 13.5° were not affected by the deformation (Sá *et al. op. cit.*). Between the southern Paramirim complex and the northwestern border of the Gavião block, another segment of Archean terrain is observed. This region is identified as the Lagoa Real region in figure 2. The basement of this complex is composed of plagioclase and microcline gneisses, with widespread inclusion of albitite veins and intrusion of granitic bodies (Sá *et al. op. cit.*). Detailed petrological study on the Lagoa Real granitic complex has been carried out by Maruéjol *et al.* (1987). According to these authors, granites were emplaced at $1.725 \pm 0.5 \text{ Ga}$. Metasomatic alteration which produced both the albitites and the associated uranium mineralization occurred at 1.39-1.36 Ga. The sub-alkaline orthogneisses resulted from the regional metamorphism associated with the thrusting (0.48 Ga) of the Lagoa Real complex over the Middle Proterozoic Espinhaço Series (Caby & Arthaud 1987).

A thick accumulation of sediments took place on both sides of the Paramirim complex during the Espinhaço orogenic cycle, which lasted from 1.7 to 1.3 Ga (Sá 1981). Deformation and metamorphism of the sediments occurred at the end of this cycle at about 1.3-1.2 Ga (Sá *et al.* 1976a). The metasediments of the Espinhaço fold belt were strongly folded with westward vergence, whereas the metasediments of the western border of the Diamantina tableland are less strongly folded and they present an eastward vergence. The deformation and the degree of metamorphism within the western Diamantina tableland decreases from west to east. The Middle Proterozoic upper sequence (Chapada Diamantina Group) was deposited in the northern part of the tableland north of latitude 12.5°S. The sediments of this sequence are unmetamorphosed and undeformed. Some further tectonism occurred subsequent to the Espinhaço orogeny, particularly normal faulting in the northern part of the Espinhaço fold belt. Acid volcanics are observed at the eastern border of the

Figure 2 – A more detailed Bouguer anomaly map of the study area together with the main geological formations of the Espinhaço fold system (Inda & Barbosa 1978). Contour interval is 10 mGal.

Figura 2 – Mapa de anomalias Bouguer mais detalhado da área em estudo, juntamente com as principais formações geológicas do Sistema de Dobramentos Espinhaço (Inda & Barbosa 1978). Intervalo de contorno de 10 mGal.

Espinhaço fold belt and the western side of the Diamantina tableland (McReath *et al.* 1981, Jardim de Sá 1981). In the Diamantina tableland, the acid volcanics were extruded during the initial stages of the Middle Proterozoic sedimentation (1.8-1.7 Ga). McReath *et al.* (*op. cit.*) describe the volcanic sequence as composed of dacites and rhyodacites of tholeiitic affinity. These rocks were metamorphosed (greenschist facies) and deformed at the end of the Espinhaço orogeny (1.3 Ga). The volcanics of the Espinhaço fold belt are rhyolites and trachytes and they are possibly post-tectonic, according to K/Ar dates (1,100-850 Ma) obtained by Távora *et al.* (1967). Metamorphism has not been observed in these rocks.

The Espinhaço fold system remained uplifted during the subsequent Upper Proterozoic sedimentation which occurred in the São Francisco basin to the west and in the Lençóis basin to the east. A thin (ca. 50 m) blanket of Cenozoic sediments occurs to the north of the Espinhaço fold system.

GEOPHYSICAL DATA Aeromagnetic Data An aeromagnetic survey was carried out by the Departamento Nacional da Produção Mineral (DNPM – Brazilian Mineral Production Department) convened to the Companhia de Pesquisa de Recursos Minerais (CPRM – Mineral Resources Exploration Company) and it covers almost the whole Espinhaço fold system (Fig. 4). A magnetic anomaly of the same areal extent as the gravity anomaly is not observed. However, short wavelength magnetic anomalies occur over the Paramirim complex and are more conspicuously developed near its western boundary, close to the Espinhaço mountain chain, thus coinciding with the position of the minimum of the gravity anomaly. According to Sá *et al.* (1976a), petrographic evidence such as epidote and feldspar recrystallization are indicative of more intense remobilization of the basement at the eastern border of the Espinhaço fold belt.

A large magnetic anomaly, to the south of Botuporã city, is also situated along the Paramirim magnetically disturbed

Figure 3 – Distribution of the gravity stations within the Espinhaço fold system. The rectangle indicates the area covered by aeromagnetic survey which is shown in Fig. 4.

Figura 3 – Distribuição das estações gravimétricas dentro do Sistema de Dobramentos Espinhaço. O retângulo indica a área coberta pelo levantamento aeromagnético mostrado na figura 4.

region and at the southern end of the large negative gravity anomaly. This negative magnetic anomaly has a minimum of about -200 nT and a complementary maximum to the south of 150 nT. The magnetic anomaly is situated mostly over the region where large and circular granitic bodies were reported by Sá *et al.* (1976b). It extends southwards and terminates at the contact between the Lagoa Real granites and the Gavião block.

The aeromagnetic data were found helpful in mapping the basement, in particular between 11°S and 12°30'S, where the basement is covered by Cenozoic sediments and Chapada Diamantina group metasediments. Over the Paramirim and Guanambi migmatitic terrains, the magnetic field is highly disturbed by short wavelength anomalies reflecting a heterogeneous basement. Over the Espinhaço fold belt and Chapada Diamantina the short wavelength magnetic anomalies are almost absent due to a deeper magnetic basement. The northern border of the Paramirim complex, as indicated by the aeromagnetic map, is situated to the north of Oliveira dos Brejinhos city, between 42°30'W and 43°W, where short wavelength magnetic anomalies terminate (Fig. 4). Also at this latitude, the western marginal gravity gradient of the negative anomaly, which parallels the Espinhaço fold belt, swings to a NE direction. Therefore, the northern limit of the large negative gravity anomaly appears to coincide with the northern border of the Paramirim complex.

Density Measurements Density measurements were

Figure 4 – Aeromagnetic survey over the northern Espinhaço fold system (Northern Espinhaço Aerogeophysical Project, CPRM-DNPM). Total geomagnetic field in nanoTesla. The dashed line indicates the contact between the metasediments and the crystalline basement. Contour interval 50 nT.

Figura 4 – Levantamento aeromagnético sobre a parte norte do Sistema de Dobramentos Espinhaço (Projeto aerogeofísico do Espinhaço Setentrional, CPRM-DNPM). Componente total do campo geomagnético em nanoTesla. A linha tracejada indica o contato entre os metasedimentos e o embasamento cristalino. Intervalo de contorno 50 nT.

carried out on 52 rock samples from the crystalline basement within the negative gravity anomaly in an attempt to estimate the mean density value of the basement rocks as well as to estimate the density of the outcropping granitic bodies. The first group of samples is from the centre of the Paramirim complex. It is composed of granitic migmatites and gneisses which yielded an average density of 2.64 g cm⁻³ and two

granites in the same area yielded a density of 2.60 g cm^{-3} . The 16 samples of the second group were taken from the Archean region to the south of the Paramirim complex, between Caetité and Lagoa Real cities. Homogeneous migmatites of granodioritic composition have density of 2.65 g cm^{-3} and microcline augen-gneisses, plagioclase gneisses, and granulites yielded densities ranging from 2.65 to 2.75 g cm^{-3} . Therefore, a gradual increase in density towards the Gavião block occurs as the lithology becomes dominated by high grade migmatites and rocks of tonalitic composition. The average density of the Paramirim complex and the Gavião block is about 2.69 g cm^{-3} . The lack of detailed density sampling across the region where the negative anomaly is observed limits the inference of the precise source of the anomaly. Density measurements neither on the metasediments nor on the acid volcanics are available.

GRAVITY INTERPRETATION The source of the negative gravity anomaly Geological evidence together with aeromagnetic data and density measurements suggest that the large negative gravity anomaly is probably caused by low density granites. Other possible sources of this high amplitude negative anomaly are firstly discussed because the evidence presented in the previous sections does not rule out the possibility that anomaly is caused either by the Espinhaço fold belt sediments or by a local thickening of the crust.

The first possible source, the Espinhaço fold belt metasediments, can be questioned on the grounds that the minimum of the anomaly occurs over the Paramirim region, therefore it lies to the east of the sediments. Although no density measurements are available, it is unlikely that the density of the highly folded Espinhaço metasediments is significantly lower than the average density of the Archean basement rocks.

Another possible source of the large negative anomaly, at deeper levels, would be a local thickening of the crust. Such a root could have been associated with the compressional events (Espinhaço orogeny) which occurred during the Middle Proterozoic. A deep seated source can be ruled out by using the gravity maximum depth formula proposed by Bott & Smith (1958). For an approximately two dimensional body, the maximum possible depth of the source of the anomaly is given by

$$Z_{\max} < 0.65 \frac{|A|_{\max}}{\left| \frac{dA}{dx} \right|_{\max}} \quad (1)$$

where $|A|_{\max}$ is the maximum amplitude (absolute value) of the anomaly and $\left| \frac{dA}{dx} \right|_{\max}$ is the maximum horizontal gradient (absolute value) of the anomaly.

The steepest measured gradient of the anomaly is 2.5 mGal km^{-1} and this occurs on the eastern margin of the anomaly over the Paramirim complex. The maximum amplitude of the anomaly is about 50 mGal . With these figures, the maximum depth to the top of the body is 13 km . The same estimate was carried out for other segments of the local anomaly and an average maximum depth of 20 km was obtained. The actual depth to the top of the body is certainly much shallower than these estimates (Bott & Smith 1958). This rules out an origin of the anomaly at the base of the crust or near it. The source of the large negative gravity anomaly must therefore lie within the upper crust. The only obvious source of such a large negative gravity anomaly in a region of exposed metamorphic basement is relatively near surface low density

granite. Similar gravity signatures are associated with granitic masses which may or may not be conspicuously exposed at the surface such as the unexposed Devonian Weardale and Wensleydale granite of NE England (Bott 1967) and the partially exposed Devon and Cornwall granites of SW England (Bott *et al.* 1958).

The regional gravity field The estimation of the regional gravity field of a large area with significant topographic variation requires the isostatic compensating effect to be taken into account.

Three Bouguer anomaly profiles together with the regional gravity field are shown in figure 5. The regional field was estimated assuming an Airy model of compensation for the observed topography. The average depth of the Moho was assumed to be 38 km . The gravity effect due to the Moho topography lacks short wavelength components. The density of the topography is 2.67 g cm^{-3} and the density contrast between the lower crust and upper mantle is 0.4 g cm^{-3} . According to this model of compensation the crust must be $3\text{--}4 \text{ km}$ thicker underneath the Espinhaço fold system relative to the eastern and western regions of the northern São Francisco Craton.

The granite modelling A two dimensional model of the granitic body is shown in figure 6, along the profile B-B' of figure 5. The granite was modelled assuming that there is a single body with no density variation within it. Two density contrasts were used with the top of the body situated near the surface. The depth to the bottom of the granite varies from 13 km , for density contrast of -0.10 g cm^{-3} , to 8 km , for density contrast of -0.15 g cm^{-3} . The width of the top is about 35 km and the width of the base is 55 km .

The minimum density contrast required to explain the observed negative anomaly is 0.06 g cm^{-3} . Density contrasts lower than this value would require the bottom of the body to go deeper in order to produce the amplitude of the observed anomaly. However, there is no solution which could fit the observed steep gradient of the anomaly.

Bott & Smithson (1967) have suggested a method of evaluating whether the sides of the granite slopes inwards or outwards by using the gradient of the anomaly across the edges of the body. The lack of detailed gravity measurements across the edges of the region where the granite is supposed to be situated does not permit the application of this method. However, the observed gravity anomaly and the outcropping geology are more consistent with an outward sloping contact as shown in figure 7. The western outward sloping margin of the granite must, therefore, underlie the folded metasediments of the Espinhaço fold belt whereas the eastern side of the granite is situated beneath the Paramirim complex.

DISCUSSION The gravity interpretation of the large negative anomaly over the Paramirim complex suggests that this anomaly is caused by a source situated within the upper crust. This source is probably granite of batholithic dimensions. We need to examine whether this is a metamorphic or post-tectonic granite of Archean-Lower Proterozoic age, or whether it is related to the Middle Proterozoic Espinhaço fold belt.

Granites are commonly found in the gneissic-migmatitic basement of the Paramirim complex (Sá *et al.* 1976a, Maruéjol *et al.* 1987). However, as shown by the gravity modelling, the low density granitic body which produces the steep negative gravity anomaly substantially underlies both the Espinhaço fold belt and the western Paramirim complex. To the south of latitude 13.5°S , the anomaly is centred over the Paramirim complex and it coincides with the region where Sá *et al.* (*op. cit.*) and Maruéjol *et al.* (*op. cit.*) have reported large circular

Figure 5 – Three gravity and geological profiles across the Espinhaço fold system along the WSW-ENE direction shown in Fig. 1. The dashed line is the smoothed regional gravity anomaly predicted by the Airy model of compensation for the observed topography, depth of compensation at the Moho, was assumed at the average depth of 38 km. Vertical exaggeration of the topography is 35 times the horizontal scale.

Figura 5 – Três perfis gravimétricos e geológicos através do Sistema de Dobramentos Espinhaço ao longo da direção WSW-ENE, mostrados na figura 1. A linha tracejada é a anomalia gravitacional regional suavizada prevista pelo modelo de compensação de Airy para a topografia observada, profundidade de compensação na Moho, aqui considerada a 38 km de profundidade. Exagero vertical da topografia é 35 vezes a escala horizontal.

Figure 6 – Two dimensional models along the profile B-B'. The granite was modelled using two different density contrasts (-0.15 g cm^{-3} and -0.10 g cm^{-3}).

Figura 6 – Modelos bidimensionais ao longo do perfil B-B'. O granito foi modelado usando dois contrastes de densidade ($-0,15 \text{ g cm}^{-3}$ e $-0,10 \text{ g cm}^{-3}$).

undeformed K-rich granitic bodies. The available 1:1,000,000 scale geological maps of Bahia State and the geological literature of this region indicate small granitic bodies outcropping in the vicinity of Boquira city (12.7°S in Fig. 2) and a large circular granitic body at latitude 13.5°S near

Paramirim city. Further evidence of granitic bodies outcropping in the region where the large negative gravity anomaly is situated has not yet been reported.

Geological information across the Espinhaço fold belt and the Paramirim complex, at the latitude of Boquira city, does not show granites intruding the metasediments but only the Archean basement. Where granites outcrop, they are frequently cut by normal faults (Espourteille & Fleischer 1980). According to these authors, the normal faulting affecting the Espinhaço fold belt postdates the Espinhaço orogeny (1.3 Ga). The Espinhaço orogeny was accompanied by low grade metamorphism. However, the observation that this metamorphism has not affected the granites of Boquira city suggests that the latter probably postdate the deformation of the fold belt. K/Ar radiometric ages obtained by Távora *et al.* (1967) both in the basement and in the fold belt yielded values ranging from 400 to 815 Ma. These dates may reflect overprint of younger events such as re-heating, mineralization or reworking (Fitch & Miller 1973).

The granites situated near Paramirim city were dated by Sá *et al.* (1976a) using Rb/Sr method and two ages were obtained: $1,530 \pm 33 \text{ Ma}$ and $1,087 \pm 27 \text{ Ma}$. These ages reflect late and post-orogenic phases of the Espinhaço orogenic cycle (1.7-1.3 Ga). On the other hand, Maruéjol *et al.* (1987) have suggested a late or post Lower Proterozoic emplacement of the granites found in the Lagoa Real complex. In view of the lack of detailed geological information of the study area, in particular concerning the granites, the relation between this postulated granite batholith with the tectonic events which affected the Espinhaço fold system is very uncertain. There are two possibilities to be

Figure 7 – Geological cross-section of the Espinhaço fold system and the granite batholith, after the gravity interpretation.

Figura 7 – Seção geológica através do Sistema de Dobramentos Espinhaço e o batólito granítico, após a interpretação gravimétrica.

discussed. Firstly, if the granite intrusion predates the Espinhaço orogeny, then the region where the granite is found should have remained as a stable block due to the isostatic tendency of low density bodies to remain uplifted throughout the deposition and folding of the sediments both in the Espinhaço fold belt and in the western Diamantina tableland. In this case, the metasediments very likely would have been folded against the uplifted granite. However, as shown in the schematic geological cross-section presented in figure 7, the axes of the folds in both the Espinhaço fold belt and Diamantina tableland are normal to the plane which defines the outward sloping sides of the granite. There appears to be a discordance between the emplaced granite and the deformed metasediments, with the granite cutting across the folding. This suggests that the main granitic batholith

probably postdates the Espinhaço orogeny.

The young K/Ar ages obtained by Távora *et al.* (1967) have been interpreted as reflecting thermal and hydrothermal events which postdate the Espinhaço orogeny (1.3 Ga). It is not possible to ascribe directly these ages to the time of the emplacement of the granitic batholith but hydrothermal events may be related to the granitic intrusion and this has to be verified with further geological studies in the area.

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