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Beautiful exotic scenario modeled by fluvial erosion

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The Vale da Lua represents the best-known outcrops of the basal unit of the Paranoá Group, which can be classified as a sedimentologic, stratigraphic and geomorphological site. The rocks of this unit are constituted by matrix supported conglomerate, badly selected, of gray color and carbonate rich, and this last feature is responsible for the differential action of the fluvial erosion, that results in peculiar forms of great natural beauty sculpted in the rocks. The São Miguel conglomerate was affected by important diagenetic processes, related to the recrystallization of most carbonate originally present as matrix and now considered as "pseudo cement", which corresponds, on average, to almost half of the rock composition. The characteristic evidenced by thin sections analyses show that the rock (clast and matrix) were submitted to low-grade metamorphism. The Vale da Lua is well preserved and to keep this condition it is necessary to increase the information to the visitors about the rocks conditions formation (including depositional and sedimentary processes), once there is great confusion by part of the public, and many believe in volcanic origin to the local rocks. It is important to emphasize in warning plates, the importance of the area preservation, the prohibition of getting rock samples and the general maintenance of the place.

Keywords: conglomerate, São Miguel River, fluvial erosion.

INTRODUCTION

The Vale da Lua valley is an important stratigraphical, sedimentary and geomorphological site, since it is constituted by well preserved outcrops of the Paranoá Group basal unit (São Miguel Conglomerate), that represents an index layer of the Proterozoic of the Brasilia Fold Belt, and shows a characteristic erosion pattern due to the dissolution of the carbonate, resulting in a peculiar landscape of rare natural beauty.

"Vale da Lua" (Moon Valley) is the local denomination of one of the occurrences of the conglomerate in the São Miguel stream. This denomination is due to the reentrance, caldrons and flat surfaces that remind the lunar surface (Figs. 1, 2). The public that visits the area has doubts concerning the origin of the rock, that is observed along 400 meters of the current bed of the drainage and that it is also present in the access trails. Many people attribute, mistakenly, a volcanic origin for the rocks present in the area. The misunderstanding on the genesis of this rocky formation is one more reason to publish the information contained in this work.

The conglomerate is not exclusive of the Vale da Lua location, but occurs discontinuously in restricted places, always in the same stratigraphic position composing an index layer that marks Paranoá Group base, in the erosive contact with the Araí Group.

Few studies were published regarding the deposicional environment, the genesis and the diagenetic evolution of the São Miguel Conglomerate, and the following works must be mentioned: Dyer (1968), Braun (1968), Barbosa et al. (1969), Dardenne & Faria (1985) and Faria (1995). The knowledge on these themes is fundamental for the understanding of the sedimentologic, geomorphologic and deposicional evolution of the sedimentary basin and the beautiful forms sculptured by water in the rocks of the Vale da Lua.

The objective of this work is to describe the facies that compose the rocks of the area, their distribution and deposicional conditions, besides the diagenetic evolution.

Figure 1 – Erosive features observed in the main section of the Vale da Lua Site. The erosion processes are controlled by the carbonate present as matrix and cement. The "natural sculptures" and the general aspects of the area are the details of more interest by the visitors.

Figure 2 – General aspect of the conglomerate that is continually reworked by fluvial abrasion. On this region the São Miguel stream flows in narrow canyons due to the carbonate dissolution.

LOCATION

The Vale da Lua is located approximately 4 km south of the São Jorge village and 28 km west of the Alto Paraíso de Goiás town along the São Miguel stream. The conglomerate was also identified in the Cordovil Stream (tributary for the left margin, located 2 km east of the Vale da Lua) and in the neighborhood of Colinas do Sul. The most important outcrops are situated in the surrounds of the Chapada dos Veadeiros National Park (south of the highway that links Alto Paraíso de Goiás to Niquelândia). Other rare outcrops are present along this same highway and, commonly, in advanced stage of weathering. Another small occurrence is referred to the Palmeiras stream (at the base of the Paranã Ridge), where the deformed conglomerate outcrops in the front of the thrust that puts the Paranoá Group over the Bambuí Group (Conde *et al*. 1994). The access to this occurrence can be done by the BR-020 federal road, and after by the GO-118 state road, following northward until the Alto Paraíso de Goiás entrance, following westward in the road that connects to Niquelândia city. Fig. 3 brings the situation map of the main occurrences

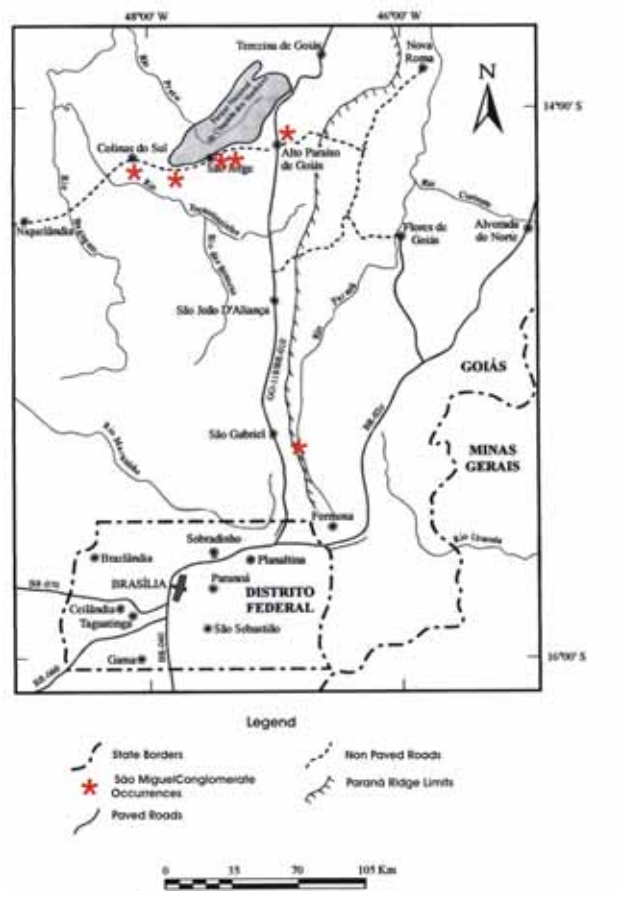

Figure 3 – Localization of the main occurrences of the São Miguel conglomerate and the main access roads.

DESCRIPTION OF THE SITE

The Vale da Lua represents one of the several outcrops of the São Miguel Conglomerate, and corresponds to 400 meters of continuous exhibitions along the bed and immediate margins of the homonymous stream. In that place the rock shows little alteration and gray coloration, with white quartzite fragment and greenish to brownish metasiltstone clasts. The dimensions of the lithic clasts vary from millimeters to more than 50 centimeters, and occasionally blocks up to 1 meter are observed. Besides the quartzite fragments and metassiltistone, there are in smaller concentration, small fragments of carbonate rock. The matrix that constitutes the rocks of the Vale da Lua area is sandy carbonatic of purple to greenish colored. There are high amounts of carbonatic diagenetic material. The exposed portions show oxidation stains and when the outcrops are out of the bed of the São Miguel stream, the rock presents a gray do dark aspect. The dark covering of the surface of the outcrops is a remarkable feature of the conglomerate and can be used as a diagnostic feature.

The data integration on the several outcrops of the São Miguel conglomerate allowed the individualization of four facies that present strong vertical and lateral interfingering. The facies are denominated of: medium to coarse massive rudite, fine rudite, masive breccia and pelitic facies.

Medium to Coarse Massive Rudite Facies

This facies is the most abundant and is represented by a badly sorted rock, with milimetric the decimetric sub-angular the sub-round fragments, with minor very round or very angular grains (Fig. 4). The rock is matrix-supported, and the matrix is represented by a badly graduated mixture of sand, silte and carbonate. The carbonate occurs in the form of euhedric crystals and as little crystalline mass. The thicker carbonate crystals show purple to reddish tones.

Figure 4 – Detail of the matrix supported conglomerate that represents the most common rock of the Vale da Lua Site.

The massive structure in layers of up to 1 meter thickness is the only structure present. In panoramic view, in the Vale da Lua, a little stratified bedding can be observed in internally massive banks and just locally it is possible to observe laminated facies.

Locally in this facies it can be observed concentric components composing quite spherical and round concretions (Figs. 5A and 5B). The carbonate and the oxide of iron are the main components of those structures of chemical origin.

Fine Rudite Facies

This facies can occur in thin massive layers and in laminated aspect, where it is identified low angle crossed beddings and convolute bedding. The fragments present similar characteristics to those observed in the previous facies. In this case the rock fragments show reduced dimensions of the grains (figure 6).

Figure 5A – Carbonate concretion formed by chemical precipitation in the early diagenetic stage. There is iron oxide contribution.

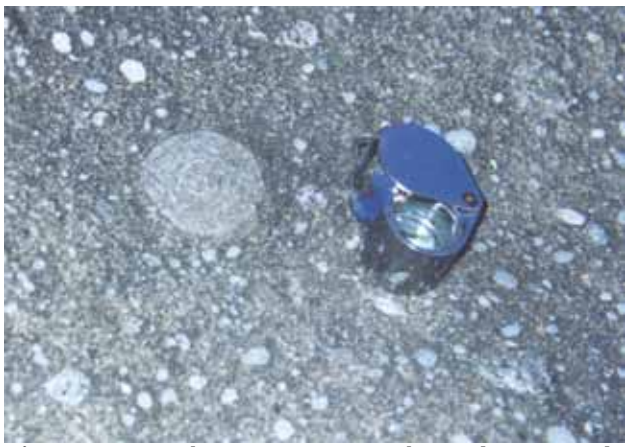

Figure 5B – Carbonate concretion observed as a pseudo clast in matrix-supported conglomerate.

The outcrops related to that facies present rougher surfaces, even when submitted to continuous reworking by river waters.

Figure 6 – Fine and laminated conglomerate, showing convolute structure and badly sorted typical of distal alluvial fan facies.

Massive Breccia Facies

This rock is characterized by clasts of the same nature of those found in the conglomerate and also occur blocks and boulders of the conglomerate. Locally the presence of fragments of fine rudites results in a mosaic of angular blocks.

The fragments vary from some centimeters up to 60 cm and they are angular, very angular and more rarely sub-round (Fig. 7). This facies is massive and just locally it can be observed diffuse bedding or erosive features in the base of diffuse channels.

Figure 7 – Intraformational breccia facies with quartzite blocks and boulders associated to de coarse conglomerates facies. Notice the low roundness of the clast.

Pelitic Facies

This facies is represented very fine sandstone, greywacke and laminated argillite that occur in restricted area and small volume. They are thin strata

that present larger lateral continuity than the previous facies where is possible to observe the following sedimentary structures of inorganic and chemical origin: horizontal bedding, horizontal lamination, dissecation cracks and marks of salt cubes (Figs. 8 and 9).

Microscopic Remarks

Studies developed in thin sections evidence the post depositional transformations impressed in the rocks that are attributed to the diagenesis and metamorphic low grade to which the rock association was submitted during the geological history. The quartzite lithic fragments present sub-grains that indicate high recristalization degree of original sandstone. The presence of small pelitic clasts, without internal mineral orientation confirms the hypothesis that the lithic fragments had not suffered metamorphism when they were reworked and submitted to erosion and transport.

Figure 8 – Pseudomorphs of salt cube formed by aerial exposition of greywacke bed.

Figure 9 – Dissecation cracks preserved in pelitic-laminated level of distal alluvial fans facies.

The observation of the thin sections corroborates the morphologic variation observed in outcrops, and the lithic fragments are sub-angular the sub-round, with predominance of the first type, and with moderate to low sphericity. In the quartzite fragments there were identified about 15% of feldspars, revealing that the original material is represented by sub arkose and nor by sandstone. The dimensions of the siltstone grains vary from millimeters to approximately 6 cm, in opposition the dimension of the sandy grains, that vary of millimeters to about 3 cm. Proportionally there is a larger percentage of sandy fragments, when compared to the percentage of siltstone fragments, and the clasts occupy 40% on average of the composition of the studied rocks.

The quartz grains represent about 13% of the studied thin sections, they show in majority, sub-angular the sub-round forms and moderate sphericity. Few grains show very well roundness and high sphericity or are very angular. The dimensions are on average 0,6 mm. These clasts are limpid and present normal extinction, what suggests a plutonic n origin. The contact between the quartz grains and the lithic fragments is punctual and indicates restricted precocious compaction. Corrosion borders, provoked by the carbonate recristalization, are observed in many quartz grains.

The feldspar is just observed in about 2% of the conglomerate and the majority of grains is altered. Some crystals are transformed into a white fine mica mass. It was possible to distinguish plagioclase and orthoclase. The roundness and sphericity, the contact type and the size of the feldspar grains follow the same pattern of the quartz grains.

Micas and oxides occur in small proportion, getting to 1%, on average, in the studied thin sections.

The fine sandy carbonate matrix that originally composed about 45% of the total rock was affected by pos depositional modifications, which caused the recristalization of great part of the carbonate, originating “pseudo cement”. The resulting crystals acquire subeuedric to euedric forms, in response to the recristalization degree.

The observation of the nature and of the carbonate types allows to conclude that a portion of the existent carbonate can be considered as true cement, in other words, crystals of carbonate formed due to the precipitation starting from the pore water in the primary intergranular spaces (primary porosity). The amount of cement and “pseudo cement” in the analyzed thin sections rise about 40%, in opposition to the amount of residual matrix, that is represented by less than 10% on average. Portions of the matrix and small quartz grains were included by carbonate during the recristalization, and this characteristic is very evident in the thin sections of all facies described.

There was significant opening of secondary porosity, probably due to the carbonate dissolution by the infiltration of meteoric waters. This process can be classified as the telodiagenetic phase.

Depositional Conditions and Source Area

The observation of the facies association, the lateral and vertical interfingering, the petrographic microscopic evaluation and the observed sedimentary structures converge for an interpretation of depositional conditions of alluvial fans (as already mentioned by Barbosa *et al.* 1968 and Faria 1995). Other alternative hypothesis for the deposition of the conglomerates, as of glaciogenic origin or turbidite environment, do not find support in the paleogeography and in the depositional processes linked to the present structures in the succession.

The deposition was controlled by normal faults of small reject associated to a crustal extension of low intensity, active in the boundary of the Mesoproterozoic and the Neoproterozoic. The reactivation of anisotropy plans (fractures and faults) presents in the Araí Group was responsible for the creating of rocky blocks and the growth of the necessary relief for the development of the alluvial fans.

The faciologic association allows establishing architecture facies classic of a complete alluvial fan, with coarser rocks representing the proximal portions of the fan and the laminated fine rudite the distal portions. The pelitic rocks observed in restricted volume, are attributed to small ephemeral lakes commonly present in the distal channeled deposits of the fan. The breccia facies represent resedimentation processes with the reworking of the pre existing deposits, before burring and lithification.

The great amount of matricial material (sandy-silt-carbonate matrix) indicates that the depositional debris flows process was the main transport and sedimentation mechanism. That petrography aspect allows to conclude that the alluvial fans were of arid climate. The sub-aqueous currents were subordinated, what is evidenced by the presence of laminated facies and of rare rounder clasts.

Due to the restricted lateral continuity and of the discontinuity of the outcrops there is difficulty in understanding the paleogeography of the fans, as well as their flow directions.

The São Miguel Conglomerate marks the beginning of the Paranoá Group deposition, in continental conditions, which were followed by a sea transgression responsible for the deposition of the marine facies of the Paranoá Basin.

The supplying source of the sediments that formed the São Miguel Conglomerate was the Araí Group, with major contribution of the Upper Metasiltstone (**MS_3**) and Upper Quartzite (**Q_3**) units. The carbonate present in great concentration in the matrix of the conglomerate or as cement and "pseudo cement" was probably originated from the limestone and marble commonly observed in the top of the Araí Group.

The climate in the source area can be inferred as dry and hot, what facilitated the mechanical disagregation of the local relief. The distance between the source area and the deposition environment was short, what is indicated by the roundness and sphericity parameters of the clasts. The dry conditions of the deposition area are corroborated by the presence of dissecation cracks and marks of salt cubes, both formed by the exposition and fast water loss in the distal portions of the alluvial fans.

PROTECTION MEASURES

The Vale da Lua is one of the several important tourist points of the Chapada dos Veadeiros region where the visitation is allowed. The site is well preserved and depredation, garbage or graffiti is not observed. The local signaling is regarded to warnings on the general care that visitors must have with the place, not being found plates allusive to the genesis of the rocks and the landscape. There is also the preservation of part of the natural vegetation, which corresponds to the forest that is distributed by several meters of extension starting from the margins, where the soil produced by the conglomerate is fertile.

The understanding for the preservation of the area is increased after the knowledge on the origin, as well as of the importance of the site. Therefore it is suggested the installation of explanatory plates on the genesis of the Vale da Lua and of the other conglomerate outcrops, aiming to wake up the visitors' interest on the geological history of these places. With this initiative it is also hoped to elucidate the confusions created around the type of rocky formation, which has a sedimentary origin and not a volcanic as many believed by many people.

Another preservation measure is based on the mapping of other conglomerate occurrences to stimulate the creation of Particular Reservations of the Natural Patrimony (RPPN), what represent the maintenance of areas destined to the conservation of the nature in private properties.

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