Terræ

Climate influence on the construction of a Proterozoic eolian sand sheet (Bandeirinha Formation, Minas Gerais, Brazil)

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Abstract : Eolian sand sheet are flattened areas with sandy deposition of arid and semi-arid environments, characterized by dunes without avalanching face. Low availability of sand is considered the main factor of generation of sand sheets. A detailed facies analysis of six measured stratigraphic sections permitted to interpret the Bandeirinha Formation, a Proterozoic siliciclastic unit of the Espinhaço Range, as ancient eolian sand sheet. This formation, 250 m thick, is composed of sandstone interbedded with three sandstone conglomerate beds. The sandstone portion corresponds to an eolian sand sheet paleoenvironment, which is formed of sets with planar parallel laminations deposited by climbing wind ripples, interpreted as zibar dunes. The sandstone conglomerate beds were deposited by high-concentrated subaqueous flows, formed within ephemeral braided river channels. The absence of typical features of alluvial fans and the composition of the conglomerate clasts (constituted of sandstone intraclasts cannibalized from the eolian sand sheet) testify the absence of mountain structures at catchment area of the fluvial system. Present and ancient desert systems record cyclic climate variations that cause the alternation of eolian and fluvial sedimentary processes. Thus, the generation of sandstone conglomerate is more probably due to an increase of precipitation than attributed to tectonics pulses.

Introduction

Eolian sand sheets are depositional systems characterized by dunes without slipface, like nabkha or zibar dunes. These may occur in hot or cold regions, in arid or semi-arid climate environments (Kocurek 1996, Mountney and Russell 2004). The absence of dunes with slipface is caused by the poor availability of sand for transport by wind, due to the following controlling factors: vegetation, water table near or intersecting the depositional surface, relative abundance of coarse-grained sand or granules, sheltered surface for cementation or gravel lag, and seasonal flooding (Kocurek and Nielson 1986, Basilici and Dal Bó 2014). Although there are many examples of Precambrian eolian deposits, few examples of Precambrian eolian sand sheets are known (Eriksson and Simpson 1998, Clemmensen and Dam 1993), and still fewer studies of ancient zibar dunes were published (Nielson and Kocurek 1986, Biswas 2005). The Bandeirinha Formation in this paper is interpreted as an eolian sand sheet with zibar dunes, and constitutes the oldest unit of the Proterozoic sedimentary succession of the Espinhaço Supergroup. The boundaries with the upper unit, the paleodepositional interpretation, and the controlling factor of the sedimentation are not yet clear (Martins-Neto 1994, Silva 1998, Martins-Neto 2000, Lopez-Silva and Knauer 2011). The aim of this paper is to present the results of a detailed facies analysis of the Bandeirinha Formation to producing an interpretation of the depositional processes and paleoenvironments and their implication for paleoclimate, paleogeographic, and paleotectonic reconstructions.

Geological Setting

The subject of this study is the Bandeirinha Formation, a Proterozoic clastic unit exposed in southern portion of Espinhaço Range, nearby the town of Diamantina, Minas Gerais (Fig. 1A). This unit takes part of the Espinhaço Supergroup, thick, which is constituted of sandstone, conglomer-

ate, mudstone and igneous rocks, showing a low grade of metamorphism (Chemale et al. 2012). The Espinhaço Supergroup is divided into two groups: Diamantina and Conselheiro Mata (Dussin and Dussin 1995). The Bandeirinha, São João da Chapada, Sopa-Brumadinho and Galho do Miguel formations constitute the Diamantina Group (Silva 1998, Martins-Neto 2000, Chemale et al. 2012) and the Santa Rita, Córrego dos Borges, Córrego da Bandeira, Córrego Pereira, and Rio Pardo Grande formations form the Conselheiro Mata Group (Fig. 1). The initial stages of lithospheric stretching and subsequent breakup of the São Francisco-Congo craton (~1.73-1.5 Ga) are supposed to have been the responsible mechanisms for creation of accommodation space of this sedimentary basin (Alkmin and Marshak 1998).

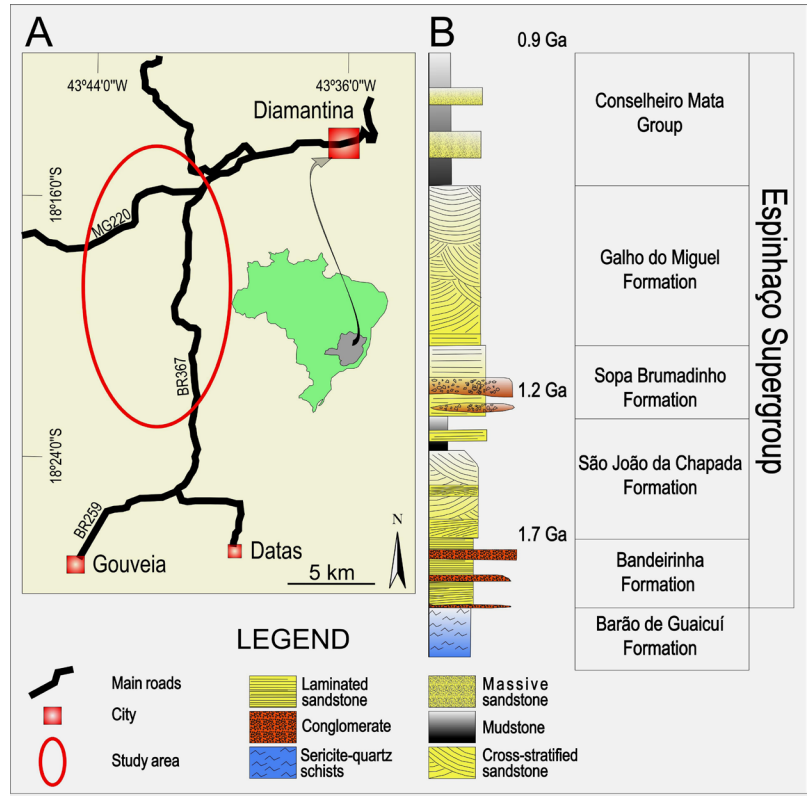

Fig. 1. (A) Location of the study area and (B) draft of the litostratigraphy of the Espinhaço Supergroup (modified by Santos et., 2013).

The Bandeirinha Formation, based on U-Pb dating, was deposited between 1.7-1.8 Ga (Chemale et al. 2012). This unit is 250 m thick and it is composed of sandstone interbedded with three episodes of conglomerate, 1.5-18 m thick (Fig. 2). The Bandeirinha Formation unconformably overlies a sericite-quartz schist unit (Barão de Guaicuí Formation) and it is overlain by a sandstone unit with planar-lamination and cross-stratification beds (São João da Chapada Formation). The stratigraphic contact with the Barão de Guaicuí Formation is partially deformed by a tectonic reactivation, probably due to the different mechanic behavior of the two formations. This tectonic stress produced an internal stretching and metamorphism at the base of the Bandeirinha Formation, which progressively decreases from the base to disappear in 10-15 m of section. The transition to the São João da Chapada Formation is considered as an angular unconformity (Martins-Neto 1994, Silva 1998, Martins-Neto 2000). However, field data do not permit to clearly visualize this unconformity,

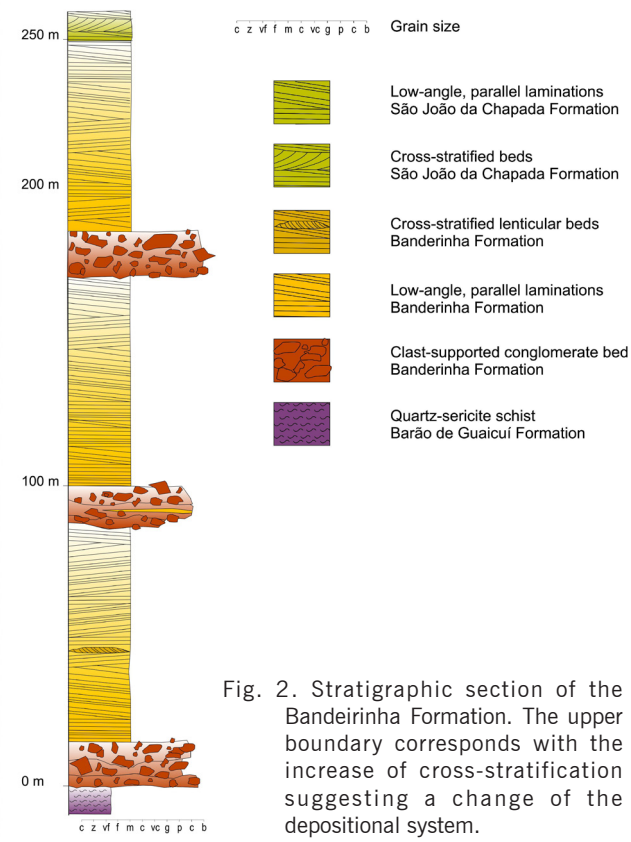

Fig. 2. Stratigraphic section of the Bandeirinha Formation. The upper boundary corresponds with the increase of cross-stratification suggesting a change of the depositional system.

which could be confuse with the original dipping of the sandstone planar lamination of the Bandeirinha Formation. The strata dipping of the Bandeirinha Formation is not easy to define in field, due to the original dipping of the planar laminations of 0-15º. However, statistical data allow defining a dipping N75-90/25-35. Silva (1998) interpreted the sedimentary succession of this unit formed in coastal and river systems, where the interbedded conglomerate beds represent fluvial mass flow deposits in alluvial fans. Only at the top of the formation this author described eolian deposits. Silva (1998) and Martins-Neto (1998) attributed the deposition of the conglomerates to tectonics pulses of regional range, and divided the Bandeirinha Formation in the three tectono-sequences (Basal, Olaria and Natureza). The depositional interpretation of the Bandeirinha Formation expressed in this paper is substantially different from the previous interpretations, as also the explanation on the forcing factors that originated the conglomerate beds.

Methods

The research activity has focused in the type-area where the Bandeirinha Formation was defined. In this site, a complete stratigraphic section, more than 250 m thick, from the metamorphic bedrock was measured. Other five stratigraphic sections, 5-25 m thick, were measured in nearby areas with the purpose to verify lateral variation of the lithofacies. In all the cases, the measurement of the section was joined to a detailed facies analysis. The lithofacies and architectural elements were described and distinguished based on grain size, sorting, type and organization of the sedimentary structures, form and dimension of the beds, characteristic of the bounding surfaces, interpretation of the depositional mechanisms. The concept herein used of lithofacies is not only descriptive (Walker 2006), but also interpretative. Indeed, this concept is based on the depositional aspects deduced by physical characteristics of the lithofacies. Moreover, in this paper lithofacies codes are not utilized (Bridge 1993a). Photos of rock expositions were arrange in photomosaics, on which bounding surfaces, relationship between the lithofacies, dimensions and shape of the architectural elements have been visualized. A large scale geological survey was executed to define the horizontal distribution of the architectural elements. Thirty-three samples were collected in the field to produce polished slabs and thin sections, which were used to examine in detail the texture and sedimentary structures of the sediments and microtexture of the grains. The low grade metamorphism of the Bandeirinha Formation did not affect the recognition of the sedimentary structures and the application of the sedimentary facies analysis method. Thus, the terminology here used is typical and related to sedimentary rocks.

Architectural Elements

Three architectural elements were identified in Bandeirinha Formation: translatent climbing ripple sandstone, cross-stratified fine-grained sandstone and sandstone conglomerate.

Translatent climbing ripple sandstone

This architectural element is composed of moderately- to well-sorted, fine- to coarse-grained sandstone. The grains of sand are rounded or well-rounded and are constituted for 95% of quartz. The grain-size distribution is bimodal, showing two modes in fine and medium-coarse grain-size. The sandstone is organized in low-angle planar parallel laminations, dipping 0-15º. The laminae are 2-12 mm thick and sometimes are characterized by a rough inverse gradation due to the presence of coarse-grained sand on the upper portion of the lamina. In outcrop, these structures are similar to the pin stripe lamination of Fryberger and Schenk (1988). The laminae are organized in sets, 0.4-1.2 m thick and laterally extended 4->9 m; their bounding surfaces are erosive, dipping 0-14º, and the basal laminae of the set are parallel to the bottom surface (Fig. 3A). Locally, asymmetrical undulating laminations may be observed interbedded with the planar laminations (Fig. 3B). These undulating structures on bed surfaces correspond to asymmetrical ripples bed forms (Fig. 3C). This architectural element forms sandstone successions more than 50 m thick and with lateral exposition more than 2 km. It is interbedded with sandstone conglomerate and cross-stratified fine-grained sandstone.

Interpretation

Hunter (1977) and Hunter et al. (1981) named climbing translatent strata deposits produced by climbing wind ripples, which are constituted of fine to coarse-grained, well-sorted sand, bimodal in grain size distribution, arranged in horizontal or

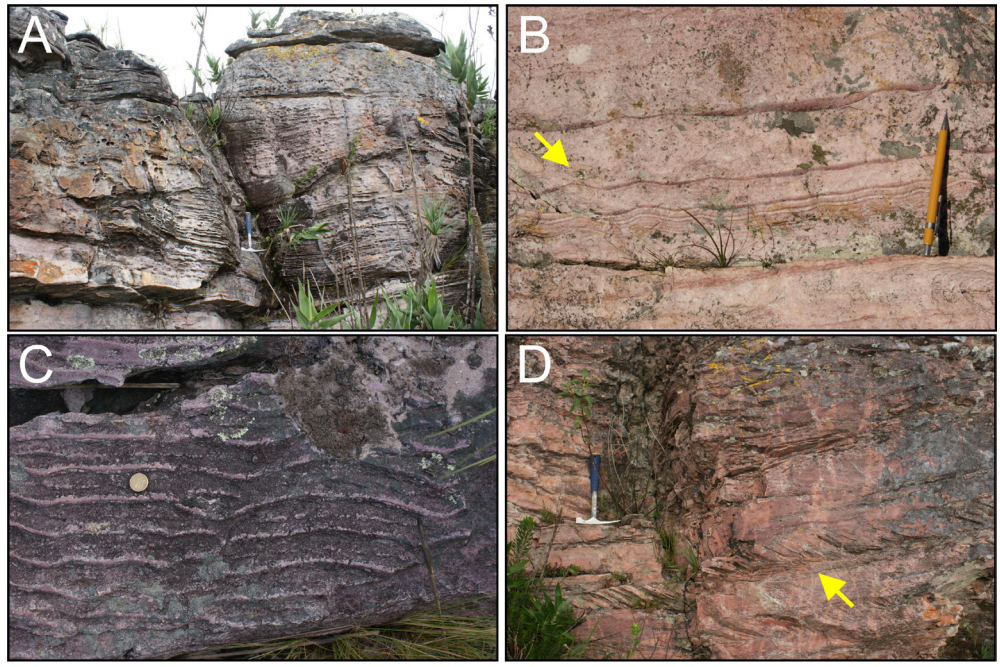

Fig. 3. (A) Low-angle, parallel laminated sandstone, corresponding to subcritical translatent climbing strata, organized in sets separated by erosive surfaces. Hammer: 0.28 m. (B) Asymmetrical laminations (arrow), interpreted as supercritically translatent climbing strata. Pencil: 142 mm. (C) Asymmetrical laminations on the upper bed surface. Note the weak asymmetry of the bed forms. Coin: 20 mm. (D) Cross-stratified fine-grained sandstone beds (arrow) form lenticular beds, interbedded with low-angle parallel laminations. Hammer: 0.28 m.

low-angle, planar and parallel laminae, commonly with inverse gradation (Fig. 3A). This architectural element corresponds with the description of the above cited authors and its deposits may be interpreted as formed by wind ripples. This interpretation is confirmed by the similarity with pin stripe lamination of Fryberger and Schenk (1988) and the presence of high rounded clasts, typical of wind transport (Mahaney 2002). Most of the observed sedimentary structures correspond to subcritically climbing wind ripples, but the asymmetrical undulating laminations can be interpreted as supercritically climbing wind ripples (Hunter 1977) (Fig. 3B and C). Climbing wind ripples are typical bedforms in eolian depositional environment, they may be found on stoss side of dunes, lower portion of the lee side of dunes, dry interdune areas, or they constitute the basic structure that form dunes without slipface, as nabkha or zibar. The geometrical characteristics of the sets of this elements and the absence of high-angle cross stratification (i.e., deposits of dunes with slipface) lead to interpret the set of climbing wind ripples as deposits of nabkha or zibar. Nabkha are anchored and active dunes with main axis parallel to the wind direction; they form behind an obstacle (Tengberg and Chen 1998, Langford 2000). Zibar are dunes with main axis perpendicular to dominant wind, which do not need obstacle to be formed (Nielson and Kocurek 1986). Both are dunes with low relationship high/short-axis length or and long-axis length compared with dune with slipface. In areas with relative supply of sediments, nabkha or zibar can superimpose and built geological bodies, characterized by sets of planar parallel or low-angle laminations separated by erosive surfaces, whose thickness and extension depend on the dimensions of the original bedforms. Nabkha and zibar cannot be distinguished by the internal structure, because similar in both of cases. However, nabkha dunes form in presence of an obstacle, which in present environments is manly represented by vegetation (Tengberg and Chen 1998). The Bandeirinha sedimentary succession does not display suitable physical obstacles that could have generated nabkhas, and the presence of terrestrial vegetation is obviously excluded. Thus, the more plausible interpretation is that this architectural element may represent zibar dunes.

Cross-stratified fine-grained sandstone

This architectural element is formed of well-sorted, fine- and very fine to fine-grained sandstone, prevalently constituted of quartz grains, organized in lenticular sets, 0.12-0.3 m high and 3-7 m laterally extended (Fig. 3D). Cross-stratification

laminae are 3-10 mm thick, and dip 21-26º; reactivation surfaces are observed (Brookfield 1977). The foresets display thin alternation of fine- and very fine-grained laminae. This architectural element forms isolated strata of 1-3 superimposed sets within the element translatent climbing ripple sandstone, with which has erosive bounding surfaces. This element represents only 2% in thickness of the measured sections.

Interpretation

The restored angle of the cross-stratification indicates that they formed for avalanching processes. Thus, this architectural element corresponds to dune with slipface. The very fine grained foreset laminae and the interbedding with wind-ripple strata, and the absence of sedimentary structures associated to subaqueous flows suggest that these structures are small eolian dunes (Hunter 1977, Kocurek 1996, Mountney 2006). Because the upper bounding surface of the cross-stratification sets is erosive, the real high of the dunes is unknown, but probably, due to restricted lateral extension and to be uncommon, they were small dimension dune bedforms. In other way, this foresets may be interpreted as rare slipfaces of zibar dunes, as observed by Lancaster (1982) in Namibia desert.

Sandstone conglomerate

In study area, sandstone conglomerate constitute three sedimentary bodies, 1.5-18 m thick; their visible lateral extension is around 1 km, but a detailed geological survey showed lateral extension for more than 4 km. The bottom surface of this element is concave-up and erosive; its top surface is apparently planar. Sandstone conglomerate are constituted of three lithofacies: structureless conglomerate, sandstone conglomerate and laminated sandstone (Fig. 4A). The structureless conglomerate represents 74% of the thickness of this architectural element; it is constituted of poorly sorted, clast-supported, pebble- and cobble-grained conglomerate; the matrix is poorly sorted, on average medium-grained sandstone. The thickness of this lithofacies is <1-5 m, its bounding surfaces are erosive and concave-up, but when its upper surface is in contact with sets of translatent climbing ripples the bounding surface appears to be planar and probably non-erosive. The conglomerate clasts are constituted of laminated sandstone, whose abundance is 87%; vein-quartz, quartzite, banded iron formation, and schist clasts have an abundance of 4, 4, 3, and 2%, respectively (Fig. 4B). Laminated sandstone clasts are angular to subrounded, with prevalence of subangular; the other clasts are rounded or subrounded. The dimension of the clasts is extremely variable. Maximum particle size of laminated sandstone clasts is 0.35 m; outsized clasts up to 3 m across occur (Fig. 4C). The other clasts have maximum particle size of 0.09 m and they do not show outsized clasts. This lithofacies does not display any internal organization of the clasts. Conglomerate beds are alternated with sandstone conglomerate without evident sequential order.

Sandstone conglomerate is 0.1-0.7 m thick, and it constitutes 23% of the thickness of this element (Fig. 4D). Maximum particle size of the clasts is 0.14 m; the matrix is poorly-sorted medium- and coarse-grained sandstone, and it is more abundant than the other lithofacies. Roundness and composition of the clasts are the same of the other lithofacies. The clasts of this lithofacies are barely more organized: discoid and bladed pebbles and cobbles display imbrication a(t) b(i) (Walker 1975) and sometimes they are aligned according a surface. The beds of this facies are commonly alternated to the laminated sandstone lithofacies. Laminated sandstone is 3% in thickness of the measured succession and is formed of medium- and fine-grained sandstone with a thickness of 0.04-0.15 cm. It forms lenticular beds laterally extended up to 3 m. The base of these sandstone beds has a gradual transition to sandstone conglomerate, but the top boundary is sharp (Fig. 4D). The sandstone displays planar parallel laminations, constituted of laminae, 3-10 mm, at times with inverse grading.

Interpretation

The concave-up bottom surface and the planar top of this architectural element is an evidence that it is the filling of channelized morphological structures, generated by subaqueous flows. The grain-size heterogeneity and the absence of internal structures of the conglomerate lithofacies suggest that high-concentrated flows deposited it (Tooth 2000, Blair 2003). More diluted subaqueous flows deposited the sandstone conglomerate lithofacies as imbrications and alignment of clasts suggests (Walker 1975). The laminated sandstone may correspond to the waning flow phase deposition after the sedimentation of the sandstone conglomerate, as suggested by the gradual transition of two lithofacies. Laminae with inverse

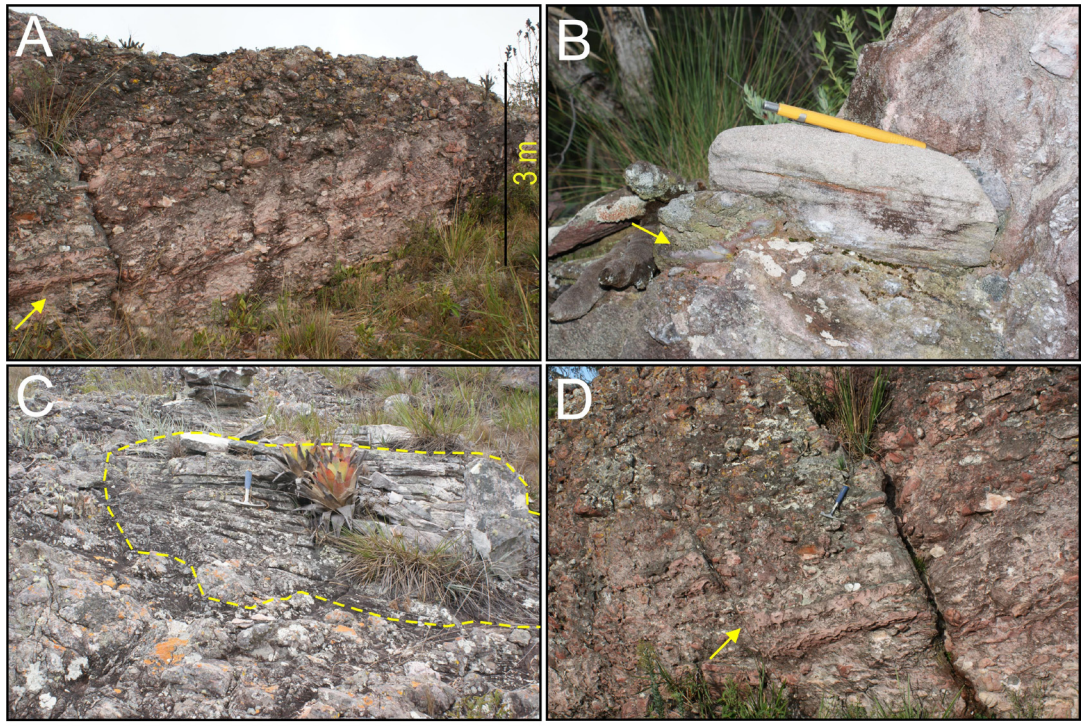

Fig. 4. (A) Sandstone conglomerate. This bed shows structureless conglomerate on the upper portion, and sandstone conglomerate in the lower portion, which are interbedded with laminated sandstone (arrow). (B) Most of the clast of the conglomerates are constituted of intraclast of laminated sandstone. A minor quantity of quartzite (arrow), vein-quartz, banded iron formation, and schist. Pencil: 142 mm. (C) Huge intraclast (marked by dotted line) of low-angle parallel laminated sandstone. Hammer: 0.28 m. (D) Sandstone conglomerate with interbedded laminated sandstone (arrow). Hammer: 0.28 m.

grading may testify fall of the water level, partial reworking of the sand by wind, and consequently an ephemeral regime of the fluvial channel (Cowan 1993, Tooth 2000, Jain et al. 2005).

Most of the clasts that constitute these deposits were originated by the erosion of the substratum, which was prevalently formed of translatent climbing ripple sandstone. Indeed, textures and sedimentary structures of the conglomeratic clasts are similar to translatent climbing ripple sandstone. Angular or subangular roundness of these clasts means that the sandstone clasts (intraclasts) did not undergo a long transport and that the translatent climbing ripple sandstone was subjected to precocious cementation. Precocious cementation has been described in arid depositional palaeonvironments by many authors (Deynoux et al. 1989, Mountney and Howell 2000, Basilici and Dal Bó). Huge boulders (up to 3 m across), found in massive conglomerate beds, may be interpreted as substratum margins fallen in the channel and transported by high concentrated flows. Few rounded extraformational clasts indicate that the water drainage area was external to the depositional basin.

Discussion

Conglomerate beds or clasts larger than granules were not ever found within translatent climbing ripple sandstone or cross-stratified finegrained sandstone elements. This indicates that the conglomerate transport and deposition were processes restricted to the formation of the sandstone conglomerate element. Moreover, the geometry and the bounding surfaces of the three sandstone conglomerate beds indicate that these constitute three depositional events physically and temporally distinct from the sandy sedimentation of the other two architectural elements. The subaqueous conglomerate sedimentation had not any relationship with the eolian sandy sedimentation, except to cannibalize previous cemented sandy deposits. Thus, the Bandeirinha Formation may be identified with two separated depositional systems: an eolian system, represented by translatent climbing ripple sandstone and cross-stratified finegrained sandstone elements, and a fluvial system, represented by sandstone conglomerate lenticular beds.

The construction of the Bandeirinha Forma-

tion was dominated by an eolian system. This was mainly characterized by flattened and long dunes without slipface, probably correspondent to the present zibar. Smaller dunes with slipface uncommonly also occurred. Eolian systems that presently are characterized by dunes without slipface, like zibar, are called eolian sand sheet.

Kocurek and Nielson (1986) attributed the formation of eolian sand sheet to an overall low rate of supply and/or availability of sand. This is mainly due to sheltered surface by conglomerate clasts or cementation, abundance of medium- to coarse-grained sand, high water table, periodic flooding, presence of vegetation, poor sandy input into the system. On the contrary, when high input and availability of sand occurs a dune field (erg) generates. Vegetation, high water table, and periodical flooding may be excluded as factors that controlled the formation of the sand sheet of the Bandeirinha Formation. Terrestrial vegetation was absent during the Proterozoic, and sedimentary features, that testify high water level, as for example adhesion structures (Kocurek and Fielder 1982), or flooding, as for example subaqueous deposits and thin mud laminae, were not observed (Tripaldi and Limarino 2008, Basilici and Dal Bó). Never pebble lags accumulations, which could have constituted potential sheltered surfaces, were found in the Bandeirinha Formation.

Currently, it is possible suppose that the absence of dunes with slipface was due to the coarser grain size than typical eolian slipfaced dunes (Kocurek and Nielson 1986) and the precocious cementation of the sand deposits. Precocious cementation in desert environments is known and associated to evaporite minerals; for example, Basilici and Dal Bó recognized in a present eolian sand sheet precocious cementation due to calcium sulfate, which constitutes an important factor for the decrease of sand availability. Direct data on precocious cementation of sands of the Bandeirinha Formation do not exist, because diagenetic and metamorphic processes modified the original cementation. However, it is possible hypothesize a precocious cementation of the sands because the deposits of the sandstone conglomerate are almost completely constituted of angular or subangular intraclasts originating from the erosion of the sandstone architectural elements.

The three sandstone conglomerate beds, which are interbedded with sandstone in the typical area of the Bandeirinha Formation, constitute sedimentary bodies isolated from the sandstone succession, as can be observed by geometrical boundaries and large lateral extension of these bodies. The sandstone conglomerate is probably constituted by overlap of various fluvial channels deposits, whose textural features, absence of sedimentary structures, and sandstone beds with eolian reworking suggest high-energy and irregular subaqueous flows. Few rounded metamorphic and sedimentary clasts of the conglomerate indicate that the water flows were generated out of the depositional basin. However the water flows should not be originated in mountain areas, because most of the clasts were formed within the depositional basin, cannibalized from precociously cemented sandstone.

Silva (1998) and Martins-Neto (1998) interpreted the conglomerate episodes of the Bandeirinha Formation as reactivation of alluvial fan deposits. Although these types of conglomerate deposits can be found in channel deposits of alluvial fan, the conglomerate beds of the Bandeirinha Formation do not represent alluvial fan systems. In fact, the alluvial fan systems are characterized by unchannelized deposits on intermediate and distal portion of the fan and by channel beds with low relationship width/thickness (as ribbon channel) (Friend 1983, Blair and McPherson 1994a and b), which are absent in the Bandeirinha Formation.

Moreover, being the alluvial fan systems characterized by a catchment area in mountain areas, the conglomerate composition of the clasts should reflect the geology of the catchment area and should be principally composed of exotic clasts. These characteristics are not observed in sandstone conglomerate of the Bandeirinha Formation, giving another element for not consider these conglomerate beds as alluvial fan deposits. In this paper, the sandstone conglomerate beds are interpreted as ephemeral braided river deposits, which were characterized of high lateral migration and swept the eolian sand sheet eroding previous eolian sandstone deposits. High concentrated water flow deposits, eolian reworked sandstone deposits, absence of sequential organization of the channel filling, and high relationship of width/thickness are characteristics of ephemeral braided rivers (Bridge 1993b).

What types of forcing factors could have caused the abrupt change from an eolian sand sheet to an ephemeral braided fluvial depositional system and vice versa? According to Silva (1998) and Martins-Neto (1998) the sandstone conglomerate were originated for tectonics events that caused a

topographic rejuvenation, providing the conditions morphological to generate coarser sediments. According to Santos et al. (2013) these processes are associated to depositional dynamic, although not well defined by the authors. Overall, desert depositional systems are characterized by alternating phases of more humid and drier periods in which subaqueous and eolian processes alternate (Langford and Chan 1989, Langford 1989, Gustavson and Holliday 1999, Kocurek 1999, Scherer and Lavinia 2006, Basilici et al. 2009, Basilici and Dal Bó 2010). Variations in precipitation can explain the changes of depositional systems from eolian sand sheets to braided alluvial plains (Fig. 5). A climate change characterized by a strong increase of the precipitation can modify the surface of the eolian sand sheet. Firstly, the presence of superficial water and/or high water level inhibited the wind activity, hindering the transport of grains by wind. Later, the subaqueous flows disrupted previous eolian forms and eroded the eolian deposits filling the channels with their intraclasts. The restoration of the dry period resulted with the interruption of the fluvial activity, and the burial of the fluvial deposits with a new eolian sand sheet.

Conclusions

The Bandeirinha Formation, 1.8-1.7 Ga, is a sedimentary succession, 250 m thick, composed of sandstone interbedded with three sandstone conglomerate episodes. The main findings of the paper are as follows.

(1) The Bandeirinha Formation was formed in two depositional environments: an eolian sand sheet, constituted of two architectural elements (translatent climbing ripple sandstone and cross-stratified fine-grained sandstone), and a braided fluvial systems, constituted of a sandstone conglomerate element.

(2) The Bandeirinha Formation is an uncommon case of thick eolian sand sheet succession. The sandstone architectural elements formed by the overlapping of zibar dunes and uncommon small dune with slipface. No evidence of subaqueous processes or high water table is present in the sandstone. The construction of the sand sheet was attributed to precocious cementation of the sand deposits by evaporite minerals, which decreased the sand availability and the capacity to generate dunes with slipface. The sandstone conglomerate was deposited in ephemeral channel rivers, characterized of high-concentrated and sporadic subaqueous flows. The interpretation of this element as alluvial fan deposit cannot be sustained because this lacks of the main features of an alluvial fan system (interchannel sheet flow deposits and channel deposits with low relationship width/thickness) and the composition of the conglomerate clasts does not reflect a drainage basin in mountain areas.

(3) The alternations between sandstone conglomerate and sandstone are attributed to climate variations. Strong increase of precipitation stopped the eolian processes of transport and sedimentation and formed braided fluvial channel that cannibalized previous eolian deposits and filled the channels with intraclasts. The tectonic interpretation to explain these alternations cannot sustained, due to the reinterpretation of the sandstone conglomerate as braided fluvial system and the fact that most of conglomerate clasts have an intrabasinal origin.

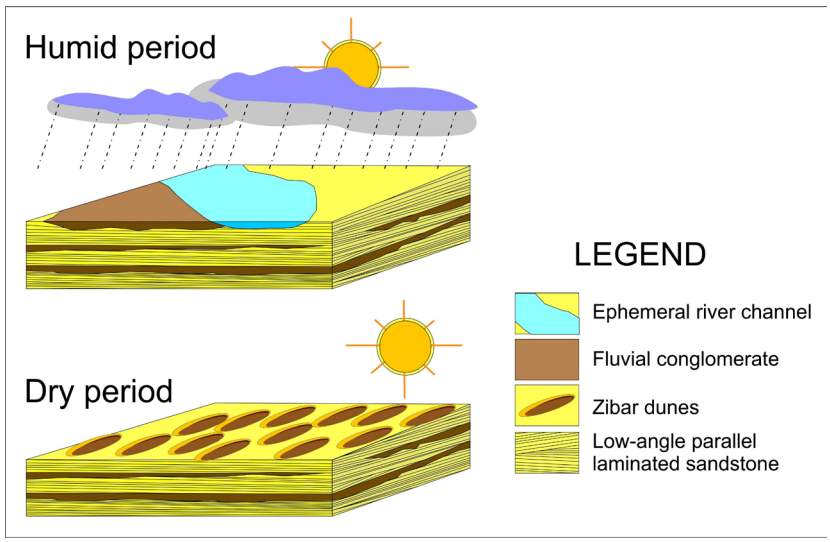

Fig. 5. Hypothetical model of generation of the Bandeirinha formation, based on the alternation of eolian sand sheet and fluvial system controlled by climate phases.

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Resumo : Os lençóis de areia eólica são áreas achatadas que ocorrem em ambientes áridos e semiáridos, onde predominam dunas sem faces de avalanche. A baixa disponibilidade de areia é o principal fator para geração de lençóis de areia. A análise de fácies de detalhe efetuada em seis seções estratigráficas permitiu interpretar a Formação Bandeirinha, Proterozoico da Serra do Espinhaço, como um antigo lençol de areia eólica. Esta formação, espessa 250 m, é composta por arenitos intercalados a três camadas de conglomerados. Os depósitos de arenitos são compostos por *sets* de laminações plano-paralelas de marcas onduladas de vento, que formam dunas do tipo zibar, e que correspondem a um paleoambiente deposicional de lençol de areia eólica. As camadas de conglomerado arenoso foram depositadas por fluxos subaquosos de alta concentração formados em canais efêmeros entrelaçados. A ausência de características de leques aluviais e a composição dos clastos dos conglomerados (intraclastos de arenitos canibalizados do sistema eólico) comprovam a ausência de estruturas relevadas nas áreas-fonte do sistema fluvial e excluem a origem por pulsos tectônicos destes conglomerados. Mais provável que a geração dos conglomerados seja devido a um aumento na taxa de precipitação e ao estabelecimento de canais fluviais efêmeros.

Palavras-Chave: Lençol de areia eólica, zibar, canais fluviais efêmeros, Proterozoico,