



# Public Understanding on Geoconservation Strategies at the Passagem das Pedras Geosite, Paraíba (Brazil): Contribution to the Rio do Peixe Geopark Proposal

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## Abstract

The Rio do Peixe basin, which is developed during the Lower Cretaceous, consists of the Sousa, Uiraúna-Brejo das Freiras, Pombal and Vertentes sub-basins. They have abundant ichnofauna represented by dinosaur tracks of theropods, sauropods and ornithomimids, these being the main objects of geological heritage in the region. The majority of palaeontological sites are found in the Sousa basin and the most important geosite in terms of distribution of fossil footprints is Passagem das Pedras (Municipality of Sousa—Sousa basin). In 1992, this area was classified as the “Valley of the Dinosaurs Natural Monument” and initially had high-quality infrastructure and trained tour guides; however, following a period of neglect, the local infrastructure became precarious. In 2014, revitalization of the museum, kiosks and walkways in Valley was performed; however, there are inefficient measures to protect the dinosaur footprints from human and natural threats. Thus, 500 interviews with the urban and rural population of Sousa in addition to traders and teachers were done, seeking public understanding of geoconservation strategies at the Passagem das Pedras geosite. Critical analysis of the results was performed as a contribution to the proposal for the Rio do Peixe Geopark. The perception is that the geoconservation strategies are not effective in protecting the Passagem das Pedras geosite or in raising the Sousa population’s awareness as to the importance of geological heritage. The other palaeontological sites of the Sousa basin are also quite vulnerable and with deteriorating geological elements. Therefore, the region currently has low potential to become a geopark.

**Keywords** Sousa basin · Passagem das Pedras geosite · Geoconservation strategies · Rio do Peixe Geopark

## Introduction

The Rio do Peixe basin (Paraíba State, NE Brazil) was originated during the Lower Cretaceous (Berriasian to Barremian) and includes four sub-basins—Sousa, Uiraúna-Brejo das Freiras, Pombal and Vertentes (Fig. 1). The sedimentary rocks of these basins constitute the Rio do Peixe group, which consists of the Antenor Navarro, Sousa and Rio Piranhas formations. In the Sousa sub-basin, a total of 25 palaeontological sites have been identified with hundreds of sauropod, theropod and ornithomimid dinosaur tracks and footprints. Seventeen were found in the municipality of Sousa, seven in São João do Rio do Peixe and one in Aparecida. Of these geosites, 15 occur in the Sousa formation, five in the Antenor Navarro formation and five in the Rio Piranhas formation (Fig. 2) (Albuquerque 1970; Mabeoone 1972; Mabeoone and Campanha 1974; Santos 2014; Santos et al. 2016).

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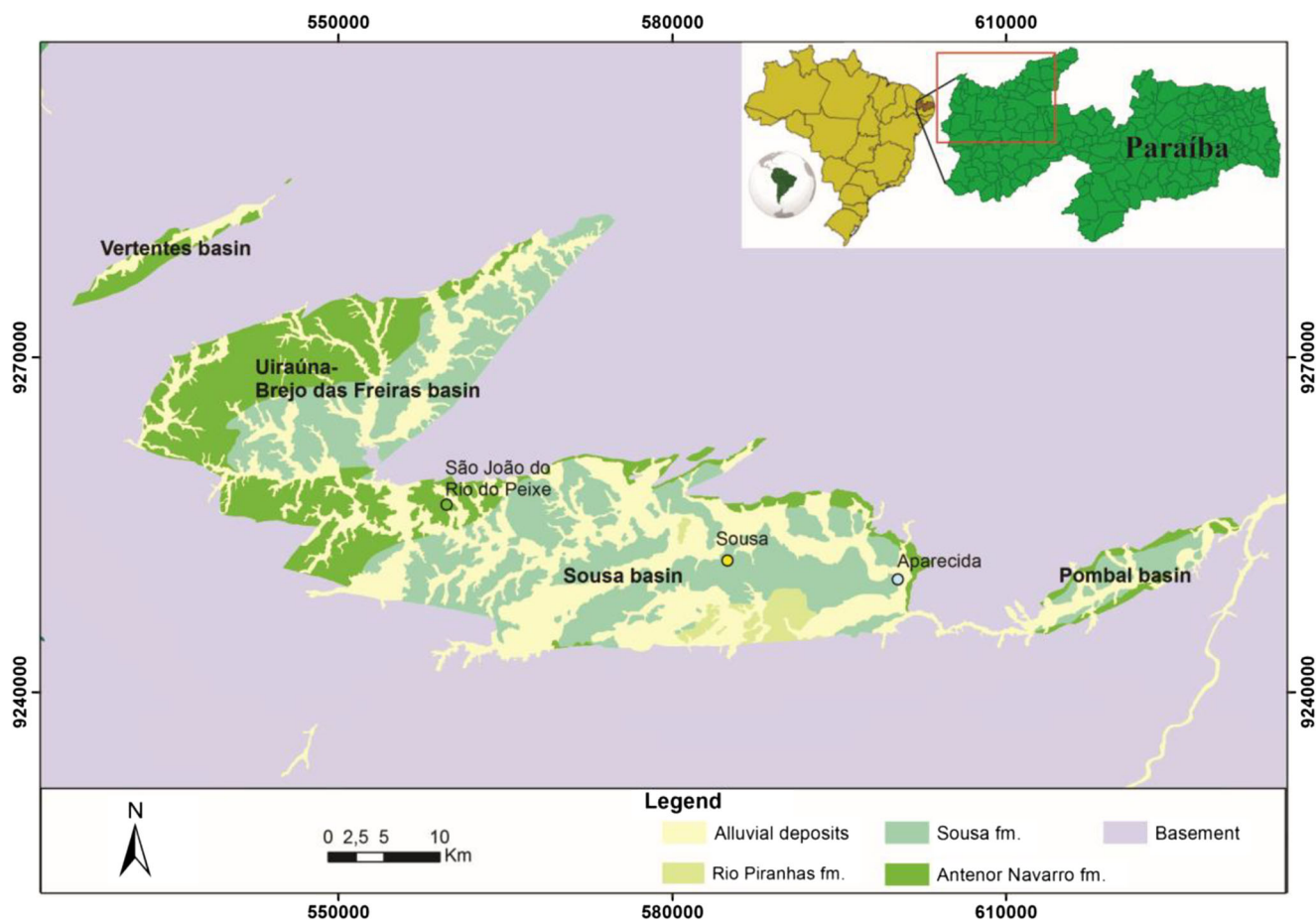
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**Fig. 1** Simplified geological map of Rio do Peixe basins (including Sousa, Uiraúna-Brejo das Freiras, Pombal and Vertentes basins) with emphasis on the Rio do Peixe group. The municipalities of Sousa, São

João do Rio do Peixe and Aparecida are also represented (modified from CPRM – Geological Survey of Brazil, sheet Sousa SB.24-ZA)

The rocks of the Antenor Navarro and Rio Piranhas formations are conglomerates and sandstones deposited in alluvial fans and braided river environments. However, the lithological characteristics of the Sousa formation (shale and siltstone intercalated with thin sandstones) suggest sedimentation in a shallow lacustrine environment (calm waters) with fluvial influence. For this reason, most fossils are found in the Sousa formation (Carvalho and Leonardi 1992; Leonardi and Carvalho 2002).

In addition to dinosaur footprints, trace invertebrate fossils produced by arthropods and annelids have also been found, together with ostracod fossils, conchostracans, plant fragments, palinomorphs, fish scales and crocodylomorph bone fragments (Leonardi and Carvalho 2007), as well as a sauropod fibula (Ghilardi et al. 2016).

The Passagem das Pedras geosite (municipality of Sousa) is the most important site in the area regarding the distribution

of fossil footprints. It is the only geosite in which different stages of a geoconservation strategy were developed—inventory and quantification of the value and vulnerability of the features, statutory designation, conservation of geological elements, valuation and promotion of the geosite, as well as monitoring of natural and human threats over time. The geosite has international scientific relevance (Santos et al. 2016).

Fossils and fossiliferous deposits are considered public property belonging to the Brazilian nation since 1942 (Decree-Law 4.146). In addition, they are considered an heritage of the Union by the Federal Constitution of 1988 (Article No. 20, I). Thus, states, the federal district and municipalities are responsible for the protection of the Brazilian natural heritage. The Constitution also considers sites of palaeontological value as Brazilian cultural heritage (Article No. 216). According with the legislation, the Brazilian palaeontological heritage is managed by the National Department of Mineral

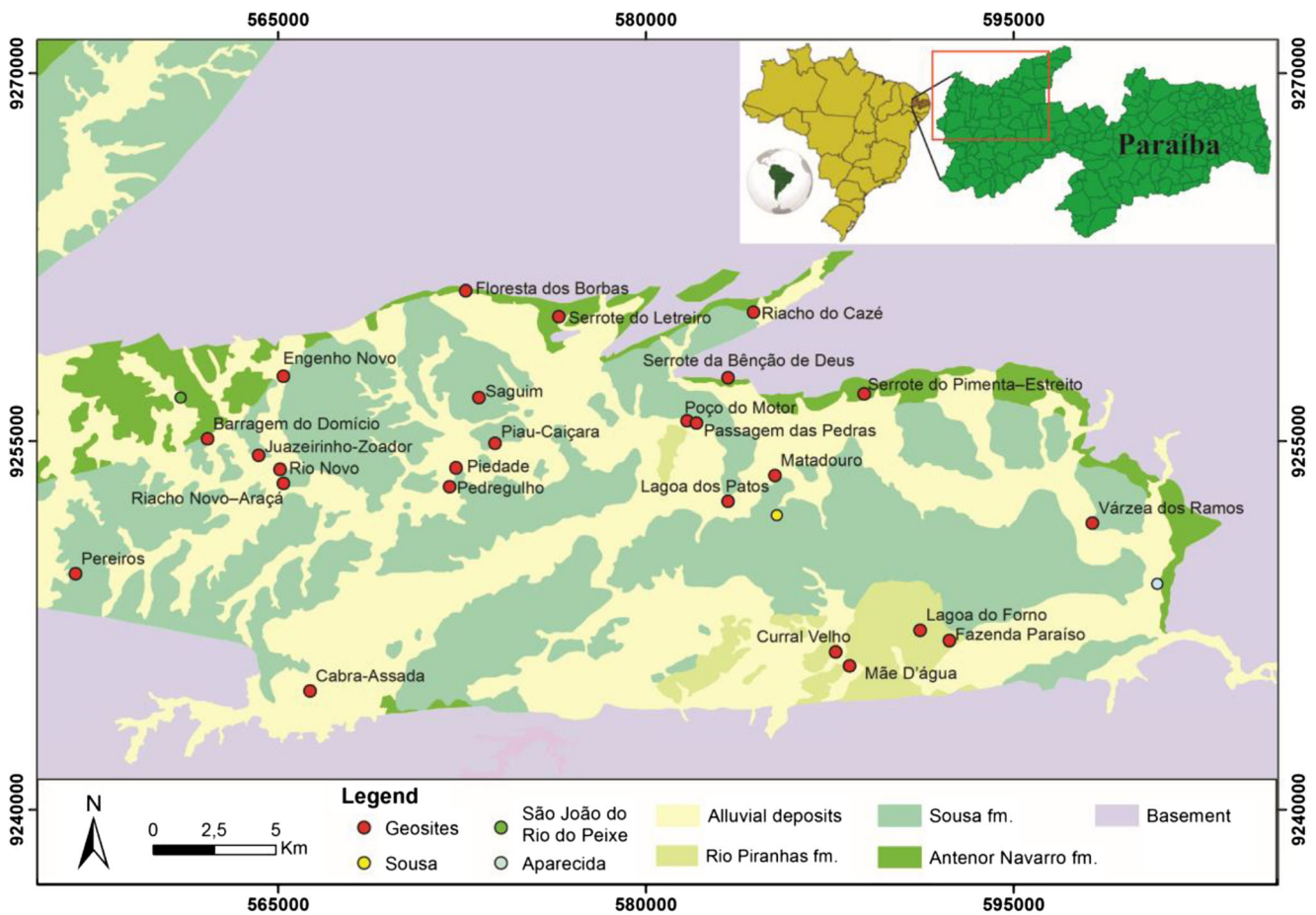


Fig. 2 Simplified geological map of the Sousa basin with the location of 25 palaeontological sites (modified from CPRM – Geological Survey of Brazil, sheet Sousa SB.24-ZA)

Production (DNPM), recently changed into National Mining Agency.

Natural Monument is one of the categories of protected areas in Brazil (Law No. 9985 of 2000), which intends to preserve restricted areas containing geological, geomorphological and remarkable landscapes due to their uniqueness, rarity, beauty or vulnerability (Article No. 15). In addition, Article No. 14 determines that landscapes, ecosystems and/or geological sites of great scientific, educational and recreational interest may be preserved through the creation of national, state or municipal parks. Thus, on 20 December 1992, the Passagem das Pedras geosite was designated by the Paraíba State as the “Valley of the Dinosaurs Natural Monument” (Decree No. 14.833).

This protected area with 40 hectares was considered one of the best-preserved palaeontological sites in Brazil. During the first decade of operation, the natural monument had not only a high-quality infrastructure providing services to visitors, but

also trained tour guides (Leonardi and Carvalho 2002; Santos and Carvalho 2011a).

However, without proper maintenance over the years, insufficient staff and reduced funding, the natural monument began to decay. In 2014, the natural monument underwent a revitalization process with the recovery of some infrastructures (museum, walkways and kiosks) but unfortunately, this occurred without considering adequate conservation of the dinosaur footprints (Santos 2014).

There is a proposal for the creation of the Rio do Peixe Geopark integrated into the Brazilian Geoparks Programme of the Geological Survey of Brazil – CPRM (Schobbenhaus and Silva 2012; Ferreira et al. 2014). Taking this proposal into account, the present study offers a contribution to the evaluation of the potential of the area to become a geopark, based on the assessment of public opinion on aspects of conservation, interpretation and promotion of the Valley of the Dinosaurs Natural Monument. This study examined whether the geoconservation strategies adopted since the revitalization

process of the natural monument (2014) have been effective in raising awareness of the local population as to the conservation of the Passagem das Pedras geosite.

## Methods

Five hundred interviews were conducted in the municipality of Sousa in 2018, which included the urban population of Sousa city with a population of 62,635 inhabitants (IBGE 2010a, b), elementary and high school teachers of the region, as well as the rural population and traders. In order to achieve more reliable data, the research sample included people with different types of professional activities in Sousa.

Questionnaires were prepared with closed questions aiming to collect quantitative data, as well as with open questions to obtain qualitative information. The interviews with teachers were carried out in private and public schools. The interviews with the urban population were conducted at their homes and with random volunteers in the city centre. Traders were interviewed in their stores and rural residents were interviewed through visits to their properties.

During the interviews, respondents' answers were annotated in an interview record. Subsequently, responses were encompassed in topics and percentages were calculated. The survey has a margin of error of 2 percentage points (95% confidence level).

The first part of the questionnaire covers information on the personal data of respondents such as gender, age, education, salary range and place of residence. The second part of the interview evaluated the opinion of the residents on

**Table 1** Questionnaire used to analyze the perception of the Sousa population regarding geoconservation strategies at the Passagem das Pedras geosite after the renovation process carried out in 2014

1. Have you ever heard of the Valley of the Dinosaurs? Yes ( ) No ( ). If **no** is selected, the interview is over.
2. Have you ever heard about the Valley reform in 2014? Yes ( ) No ( ). If **no** is selected, the interview is over.
3. Have you visited the Valley of the Dinosaurs since the revitalization process? Yes ( ) No ( ).
4. If **yes** to question 3, what has improved in the valley since revitalization?
5. If **yes** to question 3, what needs to improve (conservation and valuation) in the Valley of the Dinosaurs?
6. Do you think that the Valley of the Dinosaurs became more publicized since the reform? Yes ( ) No ( ). If **yes**, explain your opinion; If **no**, what needs to be done for better exposure of the Valley?
7. Do you think that the Sousa population has been participating in the preservation of the Valley since the reform? If **yes**, explain your opinion; If **no**, why does the population not participate?

geoconservation strategies in the Valley of the Dinosaurs after the 2014 reform (Table 1).

Similar research had previously been conducted with few adaptations in the municipality of Sousa prior to the revitalization process (Santos 2014), and in two other palaeontological areas of Brazil, Peirópolis in Minas Gerais State (Santos 2006, 2007; Santos and Carvalho 2008; Santos et al. 2018b, 2010) and São José de Itaboraí in Rio de Janeiro State (Santos 2010; Santos and Carvalho, 2011a, b, c, 2012a, b, 2013). Thus, the questionnaires used in the present study were already well adjusted due to the experience acquired in previous studies.

## Results

Among the 500 respondents, 48% declared themselves male and 52% female. About 98% of respondents live in Sousa and 2% live in other places around the city, but have employment, family or affective relationships with the town of Sousa. The age of the interviewees range from 15 to 70 years old. With the exception of the teachers, who mostly have higher education, the general education level of participants is low. The general population also has low income.

All 500 respondents have heard of the Valley of the Dinosaurs. Of these, 85% knew about the reform and 15% did not know (Fig. 3a). Among the 425 interviewees who knew about the reform, 74% have visited the Valley after the revitalization process and 26% have not visited (Fig. 3b).

The opinion of the interviewees about what has improved after the reform is expressed in Table 2. Respondents who have visited the Dinosaurs Valley since the revitalization process (313 interviewees) were asked about what still need to improve in the area (Table 3).

The majority (77%) of the 425 respondents who had visited the Valley since the reform said that the site is more publicized and 22% believe that the site has not been publicized. Only 1% of respondents could not answer the question (Fig. 3c).

Respondents who believe that the Valley of the Dinosaurs has been more publicized since the reform generally commented that now it is well covered by the media (TV, radio and Internet), and by "word of mouth" in the city and in schools. For them, the Valley is a reference point for Sousa and is the main tourist attraction in the city. In fact, several businesses have the word "dinosaur" in the name, and there are dinosaur replicas scattered throughout the city. There is even a soccer team called "Sousa Esporte Clube" that has a dinosaur on the shield. Thus, Sousa can be considered a thematic city (Fig. 4). However, respondents commented that publicity was higher just after the revitalization process and when a particular dinosaur bone was discovered (Ghilardi et al.



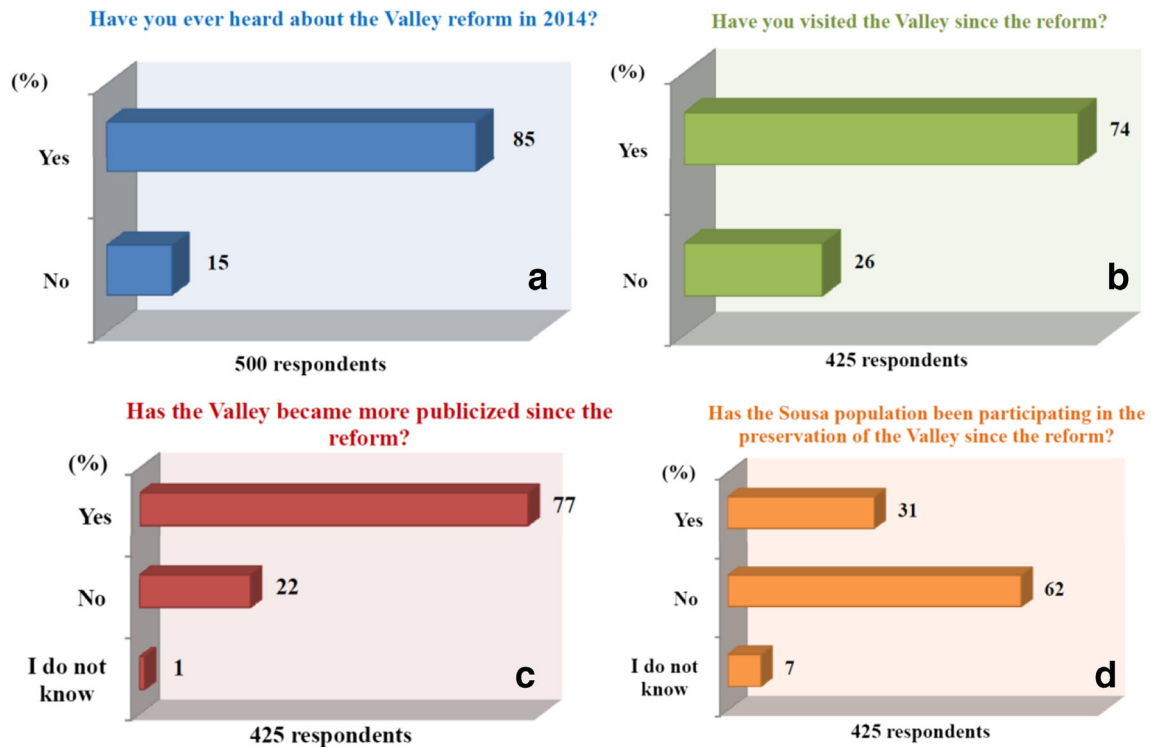


Fig. 3 Results of closed questions on the Valley of the Dinosaurs

2016), and that publicity is currently decreasing due to the lack of new attractions and investment in the Valley of the Dinosaurs.

Table 4 shows the perception of respondents who do not believe in improved publicity of the Valley of the Dinosaurs since the reform, as to what still needs to be done for better exposure of the area.

Only 31% of respondents believe that the Sousa population has been participating in preservation of the Valley of the Dinosaurs since the revitalization process, while the majority (62%) affirms that the population does not participate. Seven per cent of respondents did not answer the question (Fig. 3d).

Those who believe that the Sousa population has been participating in preservation of the Valley of the Dinosaurs since the reform commented that the residents participate by visiting and not degrading the site, and by promoting the Valley on Sousa radio stations. These respondents comment that there is a minority of people interested in the heritage, but that there are more students, researchers and tourists who participate in preservation of the site.

Table 5 shows the opinion of the interviewees about why Sousa does not participate in preservation of the Valley since the revitalization process.

Figures 5 and 6 show improvements in the Valley of the Dinosaurs. Figure 7 shows some facilities at the Valley. Figure 8 shows some threats to geosite.

## Discussions

Between 2010 and 2012, a first set of interviews was conducted in Sousa, prior to site renovation. Respondents generally commented that the Valley of the Dinosaurs infrastructure was precarious, with few employees working at the site (for cleaning, maintenance and safety, as well as tour guides). This situation was the result of a lack of political support and public and private investment. In fact, since the creation of the Valley of the Dinosaurs in 1992, no effective maintenance of the local infrastructure had been made until 2010 (except the building of the relief channel in 1998). The results of these interviews showed that the local community was aware of the complete state of abandonment of the site (Santos 2014).

With the new set of interviews carried out in 2018, it was observed that most of the interviewees had visited the Valley of the Dinosaurs since the renovation process. They commented that the museum exhibition had become more organized, the walkways were in better condition and that the general structure of the Valley is now better, with more replicas of dinosaurs, restored kiosks and trash bins around the site. However, they also said that there is an urgent need to create a restaurant, to develop new attractions for visitors and to protect the dinosaur footprints. In addition, it was mentioned that it is important to hire more tour guides and build more dinosaur replicas and a hotel in the Valley.

**Table 2** Opinion of the interviewees on what has improved in the valley since the renovation of the site (313 respondents)

Topics commented on by the interviewees	(%)	Comments made by the respondents
Museum and exhibitions	19	The outside and inside of the museum was reformed and painted. The exhibition was modified, presenting more images of dinosaurs, photos of researchers during the excavations and panels explaining the formation of footprints. The museum is better organized according to the respondents' opinion (Fig. 5).
Bridges/walkways	15	The walkways inside the Valley of the Dinosaurs were reformed (Fig. 6a and 6b).
General structure of the Valley	12	The Valley of the Dinosaurs infrastructure has improved, but they did not explain any specific improvement.
Dinosaur replicas	11	The damaged dinosaur replicas were removed from the Valley and new replicas were built (Fig. 6c and 6d).
Environment and landscape	9	The Valley of the Dinosaurs became more beautiful and pleasant after the renovation. The trees have been pruned and the environment is cleaner. Trash bins were spread over the site (Fig. 7a). It is a tourist attraction that is good for walks and picnics and with a landscape with fauna and flora specific to the Caatinga biome.
Kiosks	8	The kiosks to protect visitors from the sun have been reformed (Fig. 7a).
Guides and scientific explanations	5	There are currently more guides in the Valley and the visitor service and scientific explanations are better.
Safety	5	The Valley is safer and there are officials responsible for site surveillance.
Nothing has improved	4	The Valley continues without infrastructure and is abandoned. Nothing has changed.
Access highway.	3	The road connecting Sousa city centre to the Valley of the Dinosaurs has been paved and is now in good condition.
Footprint protection	3	Footprint protection was performed during the Valley reform.
Gift shop	2	Miniature dinosaurs, shirts and caps with themes related to palaeontology are being sold in the Valley (Fig. 7b).
Valley entrance	2	The Valley entrance is beautiful (Fig. 7c).
Others	2	More scientific research after a dinosaur bone was found in the region; Walking paths inside the Valley have been marked (Fig. 7d).

For this, it is necessary to have continuous investment to maintain the infrastructure of the area. Currently, the Valley of the Dinosaurs has two guides, one person responsible for cleaning and another for maintenance, as well as four security guards.

The general opinion of respondents is that there had been improved publicity of the Valley since the renovation process and after the discovery of a dinosaur bone in the region, but that it had subsequently decreased. They also commented that it is necessary to create adequate infrastructure at the site before further publicizing the heritage. For them, the population does not participate in the preservation of the Valley mainly due to lack of interest and knowledge on the subject.

Santos et al. (2016) presented an inventory and assessment of 25 geosites in the Sousa basin and concluded that many of these sites suffer high vulnerability and have low scientific and touristic value. At present, many geosites have completely lost the geological elements of scientific relevance or are severely deteriorated.

The local population of Sousa has never been truly involved in this project. For this reason, the Valley is considered by the locals as something that does not belong to them, which greatly complicates the implementation of conservation actions. In general, the Sousa population believes that the dinosaur footprints belong to animals that lived in a not so distant past, such as “ema” (Rhea), for example. There is a great difficulty in Sousa to accept a time scale with millions of years because the general population is very religious and follows the biblical timeline, which is not compatible with geological time. Thus, the dinosaur footprints are considered by most locals as a “legend” of the city rather than true biological evidence and consequently most people are not interested in palaeontological issues.

In spite of the renovation work in the Valley of the Dinosaurs in 2014, nowadays the dinosaur replicas and walkways are already degrading (Fig. 9a), the roof of the museum has problems, the snack bar and gift shop are closed and the footprints continue to be degraded by the erosion provoked by

**Table 3** Opinion of the interviewees about what still needs to be improved in the Valley (313 respondents)

Topics commented on by the interviewees	(%)	Comments made by the respondents
Restaurant	14	There is no restaurant in the Valley and the existing snack-bar is very often closed (this snack-bar is a private concession, Fig. 7b). They also commented that typical food and drinks of the region should be offered for sale.
Footprint protection	12	The tracks are unprotected from the natural action of the rain and flooding of the Peixe river. In addition, ruminant animals circulate freely on the outcrop with the footprints without any form of monitoring (Fig. 8).
Museum/expositions/attractions	12	Lack of attractions and activities for visitors. The expansion of the museum to hold more exhibitions and videos of dinosaurs was proposed.
Guides/best service	11	Lack of more detailed information about the fossils.
Infrastructure	8	Low quality structures to receive visitors and lack of maintenance.
Lack of investment	6	Need for public and private investment for general maintenance.
Dinosaur replicas	6	More dinosaur replicas.
Accommodations	5	No accommodation facilities inside the Valley of the Dinosaurs.
Environment/landscape	4	Green spaces in the Valley need improvement; where the very dry climate implies special care.
More publicity	3	Need for better media coverage of the activities of the Valley.
Parks/recreation areas	3	A water park with palaeontological toys for children was proposed.
Transport to the Valley	3	As the Valley is far from the Sousa city centre, a bus route should be implemented by the municipality.
More researchers	3	Need to employ researchers (biologists and palaeontologists) as there are other sedimentary levels with unexplored tracks and bones, making further fossil excavations necessary.
Political support	2	Low political support to preserve the heritage.
Damaged walkways	2	Some walkways are already degrading due to time and lack of maintenance.
Others	6	Souvenir shop, The Valley of the Dinosaurs entrance, more partnerships with educational institutions, paving the road inside the Valley that gives access to the museum, covered parking for vehicles, improve lighting, and better safety conditions inside the Valley.

the Peixe river and cattle trampling. The relief channel needs maintenance because it has been destroyed at several points (Fig. 9b).

The increasing interest in the conservation of dinosaur tracksites is a global trend (Pérez-Lorente 2000; Cobos 2004; Marty et al. 2004; García-Ramos and Piñuela Suárez 2006; García-Ramos et al. 2006; Bates et al. 2008; Santos et al. 2008a; Vila et al. 2008; Mampel et al. 2009; Díaz-Martínez et al. 2010a, b; Lockley et al. 2012; Wings et al. 2012; Enniouar et al. 2014; García-Ortiz et al. 2014; Al-Wosabi and Al-Aydrus 2015; Chabou et al. 2015; Torcida Fernández-Baldor et al. 2015; Alcalá et al. 2016; Fuertes-Gutiérrez et al. 2016; Castanera et al. 2018). In general, the problems related with geosite management in these different countries resemble the difficulties found in Passagem das Pedras geosite.

Despite the investment made to conserve geosites, if there is no local community education and awareness programme, any conservation project will tend to fail. The lack of knowledge of the local population is the main threat to the geological heritage. In addition, another mistake made by managers was the improvement of site infrastructure (museum, panels, replicas and walkways) without proper investment in effective protection of the main geological features.

One way to bring the local community closer to palaeontological heritage could be, for instance, to develop educational projects such as a “dinosaur week”, with guided tours to palaeontological sites and to the museum, lectures, workshops and recreational activities. These activities are very well developed in other places



**Fig. 4** Examples showing how the dinosaur theme is used in the municipality of Sousa (February 2018). **a** Radio “Progresso AM”. **b** Newsstand “Barracosauro”. **c** Dinosaur veterinary pharmacy. **d**

Dinosaur wood shop. **e** Shield of the football team “Sousa Esporte Clube”. **f** Dinosaur replica in one of the squares of Sousa. **g** Stationary store “Papirossauros”. **h** Dino Motel

**Table 4** Perception of respondents as to what needs to be done for better exposure of the Valley (only the 90 interviewees that do not believe that the Valley of the Dinosaurs became more publicized after the reform) (5 did not answer)

Topics commented on by the interviewees	(%)	Comments made by the respondents
Create infrastructure in the area before better publicity on the Valley of the Dinosaurs	31	The reforms in the Valley were minimal; It is important to perform a general renovation and expansion of the Valley facilities.
More populational support	23	The Sousa population does not know the importance of the Valley, which justifies the need for more awareness campaigns within the community.
More political support	19	More political commitment is needed (municipal, state and federal) for the organization and administration of the Valley of the Dinosaurs.
More investment	13	More public and private investment is needed to better publicize and reform the Valley.
Promotion in the media	6	Media in general.
Presence in TV shows	3	It is important to have regional, national and international TV shows about the Valley of the Dinosaurs.
Disclosure on the internet	3	It is necessary to increase the presence on social networks and on the web.
Others	2	Importance of publicizing the Valley on radios in Sousa and other municipalities and states, as well as creating more attractions in the Valley.



**Table 5** Opinions of the interviewees about why the population of Sousa does not participate in Valley preservation since the reform (263 respondents)

Topics commented on by the interviewees	(%)	Comments made by the respondents
Lack of interest/awareness	40	Sousa residents do not identify with the site nor with the culture of preservation, and many believe that conservation is a function of politicians. A population awareness project on the importance of the Valley of the Dinosaurs is necessary to encourage residents to participate in the maintenance of the site.
Only visitors participate	25	Only people from outside the municipality (tourists) and students have awareness of the importance of the Valley of the Dinosaurs and have greater interest in the subject. They give more value to the heritage than the general Sousa population.
Lack of attractions in the Valley	10	It is necessary to organise events with interactive palaeontological games and competitions, mainly focused on children and teenagers.
The Valley is Abandoned/without infrastructure	8	The Valley of the Dinosaurs has no infrastructure to receive visitors and appears to be abandoned.
Sousa population destroy the Valley	8	Some Sousa residents leave garbage (plastic cups, bottles and papers) in the Valley of the Dinosaurs after visiting; They go to the site to cause damage and drink alcohol and, generally, perform some act of vandalism, such as graffiti, damage to facilities and setting fires in the woods; Many people move along outcrops with tracks without supervision and some city people have already tried to steal footprints and equipment from the Valley.
Lack of political incentive	5	The indifference of politicians to the Valley of the Dinosaurs makes the local population not participate in the preservation of the area. The change of government every four years modifies interests in relation to the Valley over time, making heritage preservation difficult.
They do not believe in dinosaurs and in palaeontological studies	2	The residents do not believe that the dinosaur footprints are millions of years old and believe that this story is a "legend" of the municipality.
Others	2	Lack of school and touristic excursions and onsite investment.

such as Uberaba (Minas Gerais, Brazil), with high participation of the public (Ribeiro et al. 2015). Educational activities in local schools about the importance of fossils, as well as internships for students interested in being “guardians of the Valley” are interesting proposals for the awareness of the local population regarding palaeontological heritage. These students could also help in finding new fossils in the Sousa basin.

Regarding the protection of Passagem das Pedras geosite, partnerships between the community and private companies of the region could be used to repair the relief channel which prevents Peixe river overflow over the outcrop with dinosaur tracks, besides the construction of a roof to prevent fossils weathering, as well as to construct a fence around the outcrops to avoid the entry of animals and not allowed visitors. Similar solution was built in Peñaportillo outcrop, La Rioja (Spain) as reported in Fuertes-Gutiérrez et al. (2016).

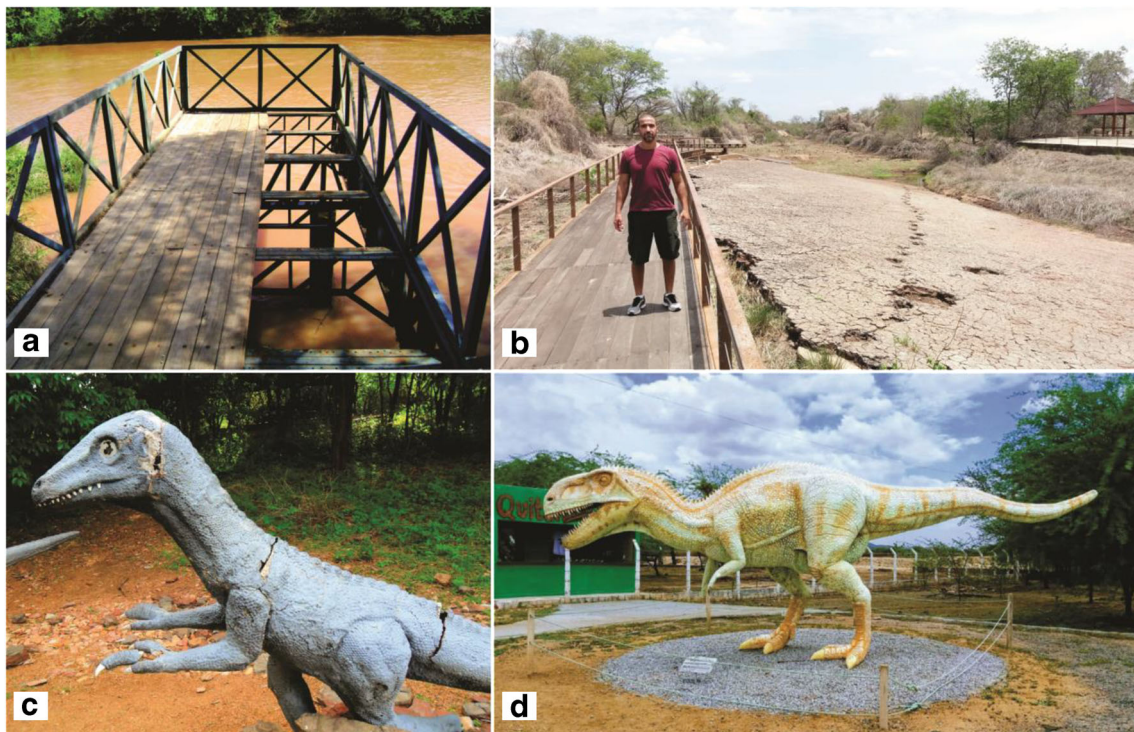
## Conclusions

The present study enabled better understanding of the perception of the Sousa population regarding geoconservation strategies in the Valley of the Dinosaurs.

The Valley of the Dinosaurs revitalization process carried out in 2014 was important to improve the museum, walkways and kiosks, but now they already need maintenance. There are no restaurants or accommodation onsite, nor projects with schools and universities or public awareness programmes on the importance of the geological heritage in the region. There is no touristic itinerary linking the Valley to other Sousa and Paraíba tourist attractions or with ecological aspects based on the flora and fauna of the *Caatinga* biome. In addition, the dinosaur tracks are still unprotected from the action of rain and flooding by the Peixe river, as well as cattle trampling. The footprints are also susceptible to vandalism and theft.



**Fig. 5** Visitor centre of the Valley of the Dinosaurs Natural Monument. **a** Main façade of the renovated museum (June 2014). **b** New museum exhibition (June 2014). **c** Old museum exhibition (August 2010)



**Fig. 6** Examples of the renovation work carried out at the Valley of the Dinosaurs Natural Monument. **a** Damaged walkway before Valley revitalization (March 2012). **b** Renovated walkway crossing the Peixe

river near the ornithomimid dinosaur track (February 2018). **c** Damaged dinosaur replica before the Valley reform (August 2010). **d** Dinosaur replica built during revitalization of the Valley (February 2018)



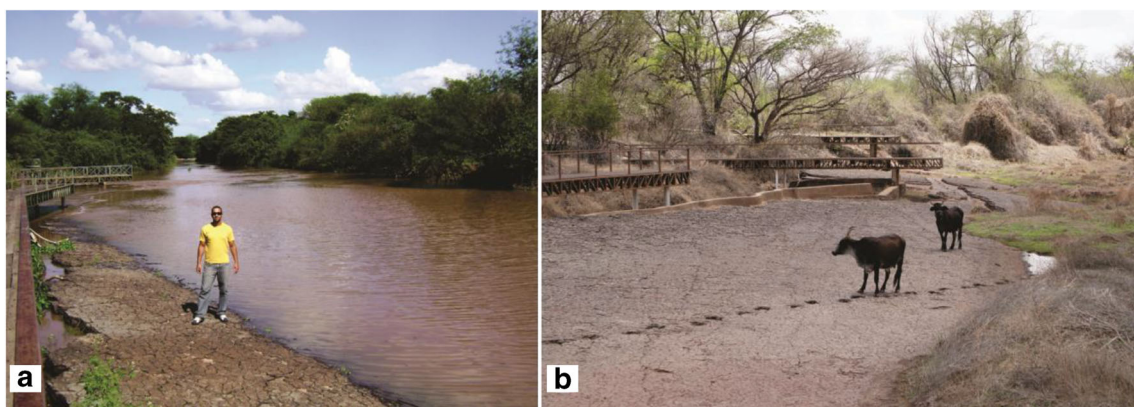


**Fig. 7** Some facilities at the Valley of the Dinosaurs Natural Monument (February 2018). **a** Kiosks and selective garbage bins built during the Valley renovation. **b** Snack bar and souvenir shop. **c** Entrance to the Valley of the Dinosaurs. **d** Information panel

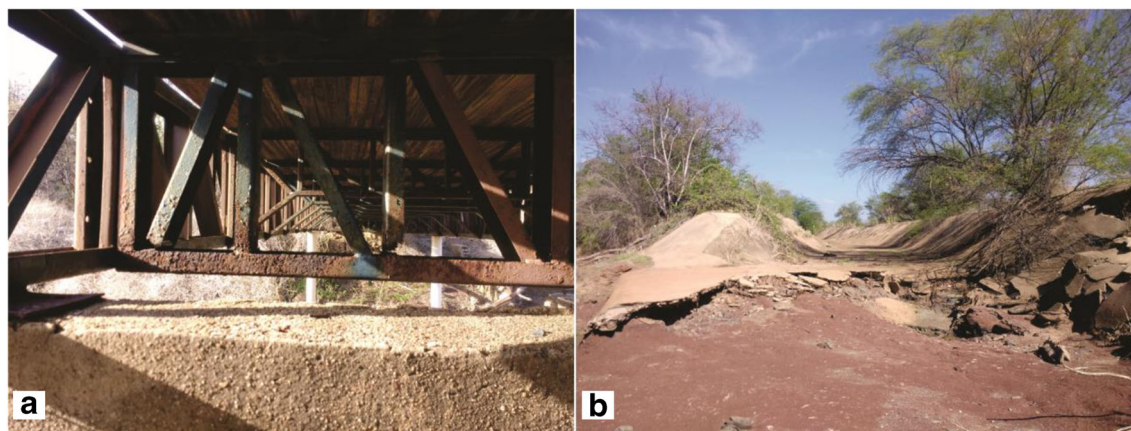
The publicizing of the Valley was greater soon after the reform and with the discovery of a sauropod fibula in the region. During this period, the Valley was much visited and raised great interest among the local population. Local radio stations in Sousa have reported improvements and difficulties in maintaining the area, as well as new palaeontological findings. Word-of-mouth in the city was intense; however, with no new attractions or continuity of the project to improve local infrastructure, the Valley of

the Dinosaurs is again falling into a state of abandonment in Sousa. The local population does not participate in the preservation of the Valley of the Dinosaurs, mainly due to lack of identity and awareness as to the heritage, and because they believe that preservation is the responsibility of the public administration.

The Rio do Peixe basin is included in the Brazilian Geoparks Programme; however, due to lack of interest of the population in relation to palaeontological features and



**Fig. 8** Valley of the Dinosaurs Natural Monument. **a** Geosite completely flooded (March 2012). **b** Ruminant animals circulating on the outcrop with dinosaur footprints. Photograph by Bernardo de Campos Pimenta e Marques Peixoto (February 2018)



**Fig. 9** Valley of the Dinosaurs Natural Monument. **a** Walkway with damaged structures (February 2018). **b** Damaged relief channel (February 2018). Photographs by Bernardo de Campos Pimenta e Marques Peixoto

due to the precariousness of the Passagem das Pedras geosite and other Sousa basin geosites, it is clear that currently the area has low potential to become a geopark. However, the proposal of the Geopark should be a logical consequence of the correct management of the geosites.

Therefore, in the municipalities with important geosites, Sousa, São João do Rio do Peixe and Aparecida, if the rural and urban population, politicians, traders and teachers continually fail to work together with researchers for the protection of geological heritage, the palaeontological elements will decay and, consequently, the area will not have the conditions to become a geopark. An effective awareness programme among local communities on geological heritage is needed before the dinosaur footprints are completely lost.

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## References

- Albuquerque JPT (1970) Inventário Hidrogeológico do Nordeste. Jaguaribe SE. Minist. Interior. Sup. Des. NE, 32, Folha n° 16
- Alcalá L, Lockley MG, Cobos A, Mampel L, Royo-Torres R (2016) Evaluating the dinosaur track record: an integrative approach to understanding the regional and global distribution, scientific importance, preservation, and management of tracksites. In: Falkingham PL, Marty D, Richter A (eds) *Dinosaur tracks. The next steps*. Indiana University Press, Indiana, pp 100–116
- Al-Wosabi M, Al-Aydrus AA (2015) Dinosaur footprint sites in Arhab area: an aspiring Geopark in Yemen. In: Errami E, Borcks M, Semeniuk V (eds) *From Geoheritage to Geoparks. Case Studies from África and beyond*. Springer International Publishing, Cham, pp 167–182
- Bates KT, Rarity F, Manning PL, Hodgetts D, Vila B, Oms O, Galobart A, Gawthorpe RL (2008) High-resolution LiDAR and photogrammetric survey of the Fumanya dinosaur tracksites (Catalonia): implications for the conservation and interpretation of geological heritage sites. *J Geol Soc* 165(1):115–127
- Carvalho IS, Leonardi G (1992) Geologia das bacias de Pombal, Sousa, Uiraúna-Brejo das Freiras e Vertentes (Nordeste do Brasil). *An Acad Bras Cienc* 64(3):231–252
- Castanera D, Pascual C, Canudo JI, Barco JL (2018) Bringing together research, geoconservation and reaching a broad public in the form of a geotourism project: the Ichnite Route of Soria (Spain). *Geoheritage* 10:393–403
- Chabou MC, Laghouag MY, Bendaoud A (2015) Dinosaur track sites in Algeria: a significant National Geological Heritage in danger. In: Errami E, Borcks M, Semeniuk V (eds) *From Geoheritage to Geoparks. Case Studies from África and beyond*. Springer International Publishing, Cham, pp 157–166
- Cobos A (2004) Valoración patrimonial de las icnitas de dinosaurio de la provincia de Teruel. *Geogaceta* 36:191–194
- Díaz-Martínez I, García-Ortiz E, Ortega Girela JM, Hurtado Reyes A, Aldaituriaga L, Benito J, Colina A, Fernández A, Martínez J, Ortega A, Pereda JC, Requeta LE, Sainz JL, Pérez-Lorente F (2010a) Treinta años de trabajo de campo en los yacimientos icnológicos de La Rioja (1980–2010). *Zubia* 28:167–178
- Díaz-Martínez I, Ladel L, Zurita-Calvo C, Haddad S, Durán I, Trachi M, Porres L, Boukil B, Sigrid Benítez S, Masrour M, Pérez-Lorente F, Boutakiout M (2010b) Importancia y vulnerabilidad del Patrimonio Paleocnológico del Alto Atlas marroquí. *Cidaris* 30:107–112
- Enniouar A, Lagnaoui A, Habib A (2014) A middle Jurassic sauropod tracksite in the Argana Basin, western high atlas, Morocco: an example of paleoichnological heritage for sustainable geotourism. *Proc Geol Assoc* 125(1):114–119
- Ferreira RV, Silva RC, Siqueira LMP, Schobbenhaus C (2014) Proposta de criação do geoparque Rio do Peixe, PB. In: *Congresso Brasileiro de Geologia*, 47, Salvador, anais, pp 142
- Fuertes-Gutiérrez I, García-Ortiz E, Fernández-Martínez E (2016) Anthropogenic threats to geological heritage: characterization and management: a case study in the dinosaur Tracksites of La Rioja (Spain). *Geoheritage* 8(2):135–153
- García-Ortiz E, Fuertes-Gutiérrez I, Fernández-Martínez E (2014) Concepts and terminology for the risk of degradation of geological heritage sites: fragility and natural vulnerability, a case study. *Proc Geol Assoc* 125:463–479
- García-Ramos JC, Piñuela Suárez L (2006) El Muja: Un Museo en torno a las icnitas asturianas de dinosaurios. In: *Fundación del Patrimonio Histórico de Castilla y León (ed) Actas Simposio Internacional Huellas que perduran. Icnitas de Dinosaurios: patrimonio y recurso*. Valladolid, pp 245–264



- García-Ramos JC, Piñuela L, Lires J (2006) Atlas del Jurásico de Asturias. Ediciones Nobel, Oviedo
- Ghilardi AM, Aureliano T, Duque RRC, Fernandes MA, Barreto AMF, Chinsamy A (2016) A new titanosaur from the Lower Cretaceous of Brazil. *Cretac Res* 67:16–24
- IBGE (2010a) Cidades. <http://www.ibge.gov.br/cidadesat/topwindow.htm?1>. Accessed 12 November 2018
- IBGE (2010b) Estados. <http://www.ibge.gov.br/estadosat/perfil.php?sigla=pb>. Accessed 12 November 2018
- Leonardi G, Carvalho IS (2002) Icnofósseis da Bacia do Rio do Peixe, PB – O mais marcante registro de pegadas de dinossauros do Brasil. In: Winge M, Schobbenhaus C, Campos DA, Berbert-Born M, Queiroz ET (eds) *Sítios Geológicos e Paleontológicos do Brasil* <http://www.unb.br/ig/sigep/sitio026/sitio026.pdf>. Accessed 12 November 2018
- Leonardi G, Carvalho IS (2007) Dinosaur Ichnocoenosis from Sousa and Uiraúna-Brejo das Freiras Basins, Northeast Brazil. In: Carvalho IS et al. (eds) *Paleontologia: Cenários de Vida*. Editora Interciência, pp 363–377
- Lockley MG, Huh M, Kim JY, Lim JD, Kim KS (2012) Recent advances in Korean vertebrate ichnology: the KCDC comes of age. *Ichnos* 19(1–2):1–5
- Mabesoone JM (1972) Sedimentos do Grupo Rio do Peixe (Paraíba). In: Congresso Brasileiro de Geologia, 26, anais, pp 236
- Mabesoone JM, Campanha VA (1974) Caracterização estratigráfica dos Grupos Rio do Peixe e Iguatu. *Estud Sedimentol* 3(4):21–41
- Mampel L, Cobos A, Alcalá L, Luque L, Royo-Torres R (2009) An integrated system of heritage management applied to dinosaur sites in Teruel (Aragón, Spain). *Geoheritage* 1(2–4):53–73
- Marty D, Cavin L, Hug WA, Jordan P, Lockley MG, Meyer CA (2004) The protection, conservation and sustainable use of the Courtedoux dinosaur tracksite, Canton Jura, Switzerland. *Rev Paléobiol* 9:39–49
- Pérez-Lorente F (2000) Experiencias de Geoconservación en La Rioja. In: Baretino D, Wimbledon WAP, Gallego E (eds) *Patrimonio Geológico y Gestión*. Instituto Tecnológico y Geominero de España, pp 179–196
- Ribeiro LCBR, Carvalho ISC, Neto FM (2015) Geopark Uberaba: relevance of the geological heritage. *Geoheritage* 7:261–273
- Santos WFS (2006) Diagnóstico para o turismo paleontológico em Peirópolis – Uberaba (Minas Gerais): a importância do Museu dos Dinossauros no desenvolvimento socioespacial local. Monograph, Universidade Federal do Rio de Janeiro
- Santos WFS (2007) Resgate histórico da mineração em Peirópolis – Uberaba (Minas Gerais): os impactos no espaço local e a ligação com a Paleontologia. Monograph, Museu Nacional, Universidade Federal do Rio de Janeiro
- Santos WFS (2010) Diagnóstico para o uso geoturístico do patrimônio geológico de São José de Itaboraí – Itaboraí (Estado do Rio de Janeiro): subsídio às estratégias de geoconservação. Dissertation, Universidade Federal do Rio de Janeiro
- Santos WFS (2014) Sítios paleontológicos, estratégias de geoconservação e geoturismo na Bacia de Sousa (Paraíba): potencial da área para se tornar um geoparque. PhD thesis, Universidade Federal do Rio de Janeiro
- Santos WFS, Carvalho IS (2008) A importância do Museu dos Dinossauros no desenvolvimento socioespacial de Peirópolis – Uberaba (Minas Gerais): diagnóstico para o turismo paleontológico. *Arquivos do Museu Nacional* 66(2):403–456
- Santos WFS, Carvalho IS (2011a) Conservação do patrimônio geológico de Sousa, Paraíba (Brasil): importância científica, educacional e geoturística. In: Simposio de Geoparques Y Geoturismo em Chile, 1, Melipeuco, actas, pp 131–134
- Santos WFS, Carvalho IS (2011b) Propostas para conservação, valorização e divulgação do patrimônio geológico de São José de Itaboraí – Itaboraí, Estado do Rio de Janeiro (Brasil). In: Simposio de Geoparques Y Geoturismo em Chile, 1, Melipeuco, actas, pp 135–138
- Santos WFS, Carvalho IS (2011c) Propostas para a preservação do Parque Paleontológico de São José de Itaboraí (Brasil) a partir da percepção populacional. *Anuário do Instituto de Geociências (UFRJ)* 34(2):24–37
- Santos WFS, Carvalho IS (2012a) Efeitos positivos e negativos da mineração em São José de Itaboraí, Itaboraí (Estado do Rio de Janeiro, Brasil). In: Henriques MH, Andrade AI, Quinta-Ferreira M, Lopes FC, Barata MT, Pena dos Reis R, Machado A (eds) *Para Aprender com a Terra, Memórias e Notícias de Geociências no Espaço Lusófono*. Imprensa da universidade de Coimbra, Portugal, pp 321–330
- Santos WFS, Carvalho IS (2012b) Parque Paleontológico de São José de Itaboraí (Brasil): propostas para a preservação do patrimônio a partir das opiniões da população de Cabuçu. In: Henriques MH, Andrade AI, Quinta-Ferreira M, Lopes FC, Barata MT, Pena dos Reis R, Machado A (eds) *Para Aprender com a Terra, Memórias e Notícias de Geociências no Espaço Lusófono*. Imprensa da universidade de Coimbra, Portugal, pp 331–340
- Santos WFS, Carvalho IS (2013) The public opinion of the teachers about the mineral exploitation in São José de Itaboraí Basin – Itaboraí (Rio de Janeiro State, Brazil). *Rend Online Soc Geol It* 28:133–136
- Santos VF, da Silva CM, Rodrigues LA (2008a) Dinosaur track sites from Portugal: scientific and cultural significance. *Oryctos* 8:77–88
- Santos WFS, Carvalho IS, Fernandes ACS, Ribeiro LCB (2008b) O patrimônio mineiro em Peirópolis – Uberaba, Minas Gerais (Brasil): potencial para o uso geoturístico. *Memórias e Notícias* 3: 515–521
- Santos WFS, Carvalho IS, Fernandes ACS (2010) Mineração versus Paleontologia: uso e ocupação da serra do Veado em Peirópolis – Uberaba, Estado de Minas Gerais (Brasil). *Anuário do Instituto de Geociências (UFRJ)* 33(2):74–86
- Santos WFS, Carvalho IS, Brilha JB, Leonardi G (2016) Inventory and assessment of palaeontological sites in the Sousa basin (Paraíba, Brazil): preliminary study to evaluate the potential of the area to become a geopark. *Geoheritage* 8:315–332
- Schobbenhaus C, Silva CR (2012) Geoparques do Brasil Propostas. CPRM – Serviço Geológico do Brasil
- Torcida Fernández-Baldor F, Díaz-Martínez I, Contreras R, Huerta P, Montero D, Urién V (2015) Unusual sauropod tracks in the Jurassic-cretaceous interval of the Cameros Basin (Burgos, Spain). *J Iber Geol* 41(1):141–154
- Vila B, Oms O, Marmi J, Galobart A (2008) Tracking Fumanya footprints (Maastrichtian, Pyrenees): historical and ichnological overview. *Oryctos* 8:115–130
- Wings O, Falk D, Knötschke N, Richter A (2012) Excursion guide B1: the Early Cretaceous dinosaur trackways in Múnchhagen (Lower Saxony, Germany)—the natural monument ‘Saurierfährten Múnchhagen’ and the adjacent Wesling Quarry. In: *Dinosaur tracks 2011. An international symposium, Obernkirchen, April 14–17, 2011. Abstract volume and field guide to excursions*. Göttingen: Universitätsdrucke Göttingen, pp 113–142