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Communication regarding the geology and vertebrate palaeontology of the Adamantina formation (Bauru group, upper Cretaceous) in Campina Verde, Minas Gerais State, Brazil

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ABSTRACT

Several geological events occurred on the surface of the earth with the division of the megacontinent Gondwana, including volcanic activity involving extensive lava flows, thus locally and regionally altering the surface's geology. Lava flows in the Serra Geral formation predominantly consist of volcanic lava fissure-derived basalt. Sedimentation upon extrusive igneous rocks occurred after this volcanic event, leading to the deposition of sediments from three formations (Adamantina, Uberaba, and Marília) collectively comprising the upper Cretaceous Bauru group, beginning about 83 million years ago. This was a period when large animals inhabited the planet, including the study area; the Adamantina formation is the largest and oldest. The city of Campina Verde is located there and is where most studies were carried out; the region is known as fossil field.

Keywords: Bauru group, stratification, fossil, sediment, Campina Verde.

RESUMEN

Varios eventos geológicos ocurren sobre la superficie de la Tierra con la división del megacontinente de Gondwana, incluyendo actividades volcánicas con extensos flujos lava, tanto local como regionalmente, que alteraron la geología de superficie. Los flujos de lava en la Formación Serra Geral consisten en su mayoría de lava volcánica fisurada - derivada del basalto. La sedimentación sobre las rocas ígneas extrusivas, ocurrió después de este evento volcánico, depositando los sedimentos de tres formaciones (Adamantina, Uberaba, y Marília) que comprenden el Grupo Bauru del Cretáceo Superior, y que inicio hace 83 millones de años aproximadamente. En este periodo habitaban grandes animales en el planeta, incluyendo el área de estudio; la Formación Adamantina es la más grande y antigua. La ciudad de Campina Verde, localizada en esta zona, es donde la mayoría de los estudios se llevaron a cabo y es conocida como un campo de fósiles.

Palabras clave: Grupo Bauru, estratificación, fósil, sedimento, Campina Verde

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Introduction

The Bauru basin in southern Brazil and northeastern Paraguay is related to tectonic and volcanic activity as part of Gondwana during the Cretaceous period. The basin covers about 370,000 km^2 in southern and central Brazil. Fernandes and Coimbra (1996) identified the Caiuá group (Goio Êre, Rio Paraná and Santo Anastácio formations) and the Bauru group (Admantina, Uberaba and Marília formations).

The Bauru group's three sedimentary formations were deposited by wind and water, beginning 83 million years ago. These formations crop out in the states of Goiás, Mato Grosso, Mato Grosso do Sul, Minas Gerais (MG), Paraná and São Paulo and north-eastern Paraguay, covering an area of 370,000 km^2; sedimentation occurred in a hot, semi-arid climate, the main event occurring during the upper Cretaceous period (Brito, 2001).

The Bauru group's three formations (in ascending order) are the Adamantina, the Uberaba and the Marília formations. The Uberaba formation is only found in the area surrounding the city of Uberaba, MG, while the other two are found in every occurrence of the Bauru group. This report will emphasise the Adamantina formation which was studied in the Triângulo Mineiro region, specifically near the city of Campina Verde, MG.

The Bauru group's rich fossil locations from the upper Cretaceous period are found in the west of MG in central Brazil; this is the earliest geological period represented in this area. Triângulo Mineiro palaeontological knowledge has been developing at Pontal do Triângulo Mineiro (in the Campina Verde and Monte Alegre de Minas area) since late 1930 and more recently in Carneirinho, Gurinhatã, Iturama and Prata.

Recent discoveries have filled in gaps in our knowledge, yet much work still remains to be done.

Von Huene (1934) recovered fragmentary fossil sauropod dinosaur remains while conducting palaeontological reconnaissance in Campina Verde in 1910; Barcelos (1984) recognised the deposits in which they were found as being Adamantina formation (Fernandes and Coimbra). Researchers from Faculdade de Ciências Integradas do Pontal Palaeontological Group (FACIP) visited the field area and collected a number of isolated invertebrate and vertebrate fossil specimens. Only a single paper describing dinosaur remains came from these studies (Candeiro, 2007).

Methodology

The studies were conducted in Campina Verde during 2009 by a group of researchers from the Universidade Federal de Uberlândia's Geology Laboratory (LABGEOL) in Pontal with the support of the municipal government. The methodology involved using several research publications on work in Campina Verde regarding the region's geology and palaeontology, as well as direct observation of specimens housed in the LABGEOL collection. The arrangements proposed by Fernandes and Coimbra (1996) and Dias Brito *et al*., (2001) were followed for defining the Bauru group's stratigraphic units.

Four strategic fossil localities were chosen during the fieldwork based on information from local farmers to facilitate the LABGEOL paleontological group's excavations and research; the first two localities (P1 and P 2, Figure 1) are located where road 364 is being paved at a great rate of advance.

The third locality (P 3, Figure 1) is at the crossroads of road 364 with MGT 484, MGT, leading to Gurinhatã, MG; 364 continues towards the states of Goiás and Mato Grosso (it is also called the São Paulo – Cuiabá road). The fourth locality (P 4, Figure 1) is at the margin of road 364 on a farm, where fossil remains of a crocodile were taken to the Universidade de São Paulo (USP) in Ribeirão Preto in early 2008.

Excavation materials, such as geologic hammers, tips, spatulas and brushes, were used at these locations. Paper boxes and plastic bags were used for the fossil remains to preserve specimens; another field method involved using hydrochloric acid on the rocks to test whether calcite existed and whether there could have been a fossil in the rock in the case of reaction. A pen was also used to record the collections selected and define GPS coordinates in the camp book.

Geological setting

Barcelos (1984), described the Adamantina formation near the city of Uberlândia in Triângulo Mineiro and Goiás State. The first outcrops appear in the city of Monte Alegre de Minas and continue in the direction of the city of Caçu, Goiás State, always beingon top of hills at around 50 to 100 m above the base formed by the sandstone in this formation.

Between Monte Alegre de Minas and São Simão (Goiás State), passing through Ituiutaba, Barcelos (1984) described the Adamantina formation sediments as variegated bimodal coarse grained and relatively well-rounded sandstone,with a sparse matrix of fine sandy silt and clay. There are also carbonate nodules and layers. The sandstone has a massive aspect but it is rich in sedimentary structures; these are represented by layers having sandy

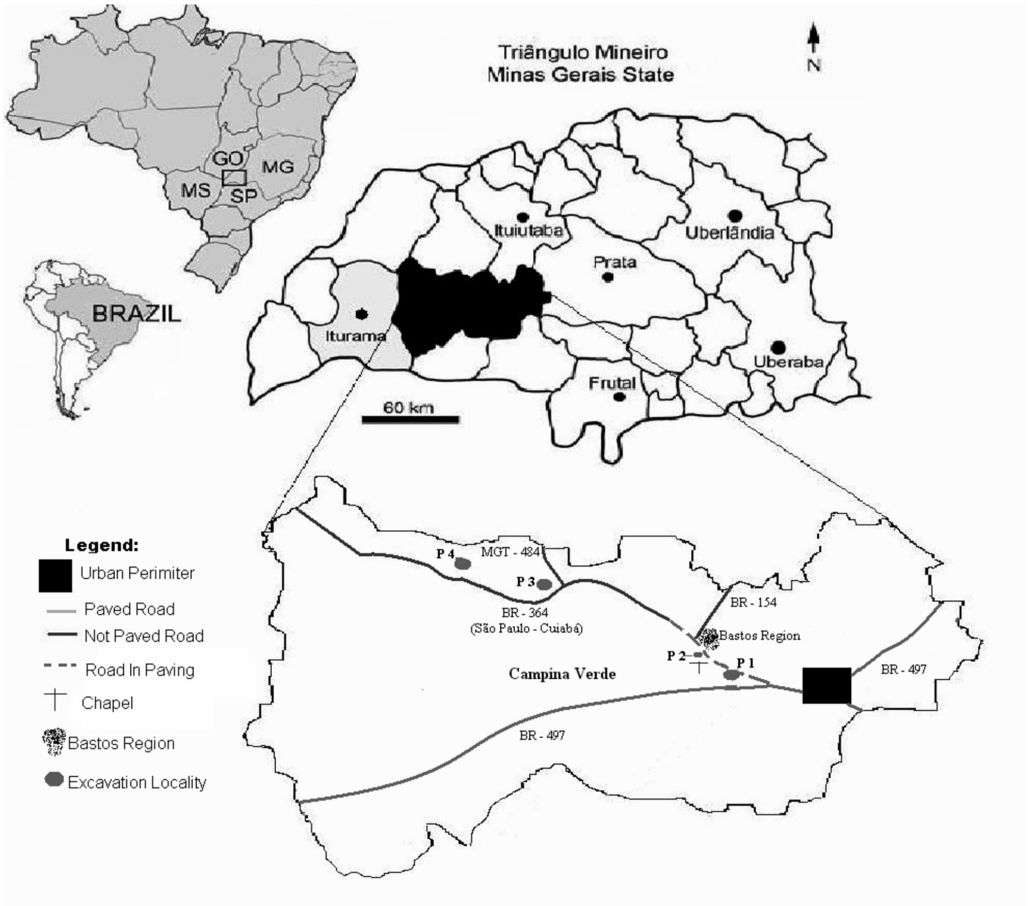

Figure1: Geographic map highlighting the locations of study. Prepared by OLIVEIRA, E. F.; RANGEL, C. C.

stratification across small, deformed and broken layers of sandstone and coarser sandstone carbonate pseudo-nodules.

Sediments dominate towards the extreme west of the Triângulo Mineiro, beyond the area around Veríssimo which is in close contact with the Uberaba formation, extending towards Prata, Monte Alegre de Minas, Campina Verde, Iturama and Santa Vitória.

The Adamantina formation represents the Bauru group's greatest extension, having a catchment area greater than that of the other formations (Uberaba and Marília); the Adamantina formation covers a large area of the Triângulo Mineiro.

According to Fernandes and Coimbra (1996), the Adamantina formation consists of a combination of very fine-grained sandstone and fine pink to brown silty mudstones, with brown intercalation; this is usual in massive stratification or plane parallel bedding, alternating with medium and small cross-bedding. The unit often displays other hydrodynamic structures such as ripple marks, cross-lamination thrusting, features cutting and filling gaps with intraformal conglomerates with argillaceous silt intraclast grading features at the top.

The Adamantina formation consists of thin and very thin sand and silty mudstone beds with cross stratification and clay lenses (interbeds). These beds range from massive to plane-parallel strata alternating with cross-stratification layers containing small to medium pebbles (Fernandes and Coimbra, 1996).

Very red sediments have been found in the Adamantina formation in the Campina Verde region but there are also dark grey fluvial sediments. Concerning sedimentary structures, the Adamantina formation has horizontal stratification with fine sediment, coarse sandstone and conglomerate inter beds, with layers of clay and pebbles (Figure 2).

The Adamantina formation's rocks have not changed much since deposition, especially their reddish, sometimes brown tones, so it is easy to differentiate them from other kinds of rocks. Extensive bioturbation in this formation demonstrates that this region had rich invertebrate fauna living in extensive communities. Another factor making Campina Verde an important site for paleontological research is the frequent discovery of fossil remains, such as a recently discovered reptilian, a predecessor of a crocodyliform (Candeiro *et al.*, 2010).

Vertebrate palaeontology

Palacontontological fieldwork carried out near Campina Verde in 2009 resulted in the discovery of isolated elements representing several invertebrate

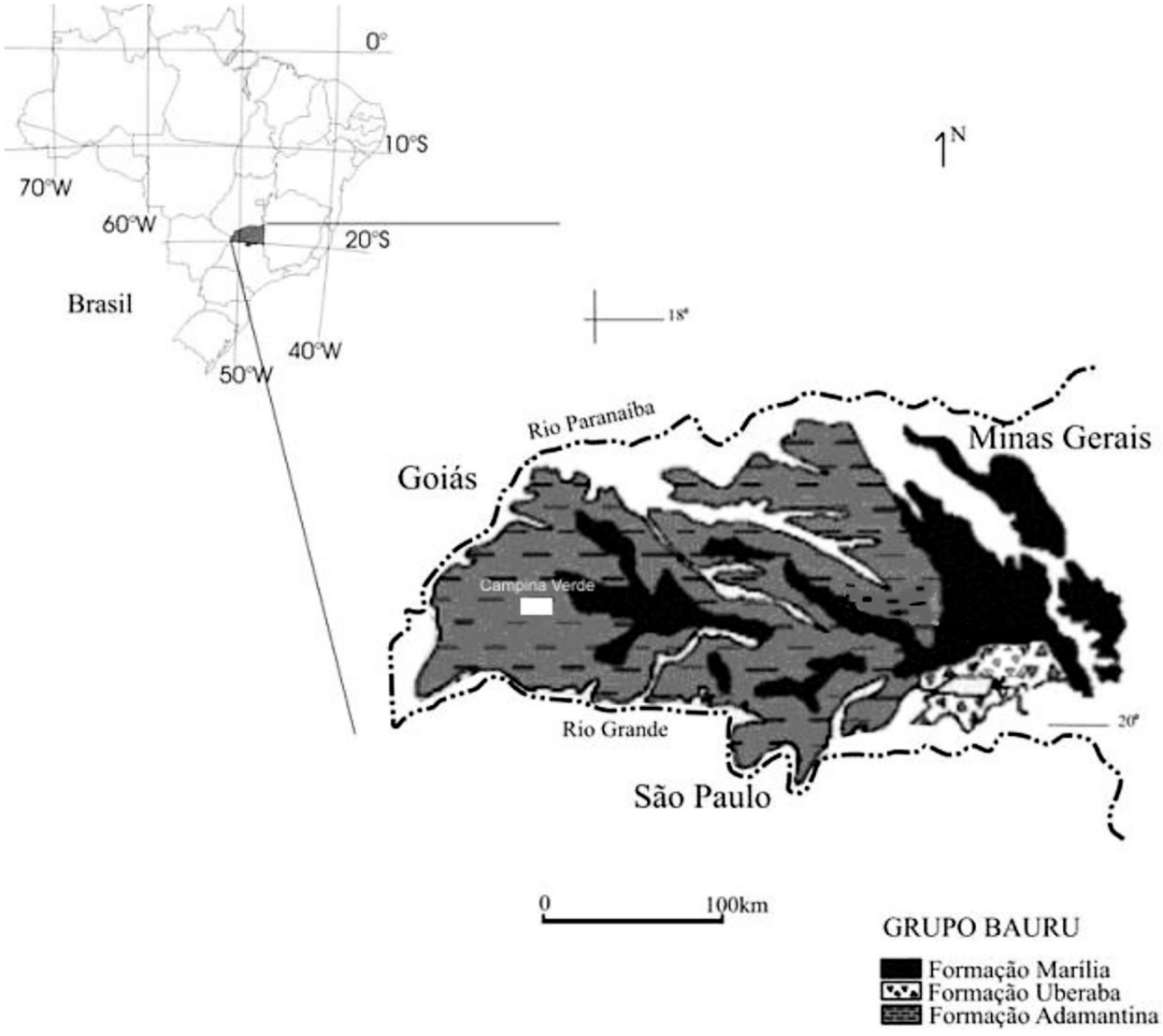

Figure 2: Geological map of the Triângulo Mineiro region, Minas Gerais State, Brazil (modified from Fernandes and Coimbra, 1996)

fossil and vertebrate taxa (Figure 3). Although generic level identification is impossible, due to the specimens' fragmentary nature, the faunal list includes crocodyliforms (Crocodylomorpha indet.), dinosaurs (Sauropoda, Theropoda indet., Abelisauroidea), other vertebrates (Vertebrata indet.) and possible molluscs (Gastropoda indet.). The theropods are represented by Abelisauroidea teeth which have labial and lingual faces which are more convex in cross-section near the anterior edge and flatter posteriorly; the lingual face is slightly concave proximodistally and the cross-sections are exactly as in the Abelisauroidea. Crocodilian eggs, previously unreported from Campina Verde, are represented by several elements. Numerous isolated mesoeucrocodilian teeth and bones indicate the presence of Mesoeucrocodylia indet.

Adamantina formation palaeontology in the Triângulo Mineiro region is rich in fossil materials and marks by Cretaceous period animals. The Adamantina formation has a remarkable faunal record of essentially vertebrate taxa; dinosaur remains are the most representative ones recorded to date (Candeiro, , 2010).

According to Dias-Brito *et al.,* (2001) the Adamantina formation's fossil sediments are primarily represented by vertebrates (remains of crocodylomorphs, dinosaurs, turtles, frogs, fish, snakes), plants (Charophyta) and molluscs (conchostraceans and ostracods).

The Adamantina and Marília formations account for most fossil records related to the Bauru group and they are where dinosaur fossil records are most extensive for this period in Brazil. saurischian dinosaur records in the states of Goiás, Mato Grosso, Minas Gerais and São Paulo include sauropods (long-necked herbivorous dinosaurs) and theropods (carnivorous dinosaurs).

This region, located in extreme west of MG, represents a promising area and certainly much more research can still be carried out in the Campina Verde region and, with the collaboration of the LABGEOL palaeontological group's services contracted by the municipality, a new point of palaeontological or archaeological research can be created in the Triângulo Mineiro (i.e. another palaeontologyarea which has been studied since 1940 is already situated in the Uberaba region, called Peirópolis).

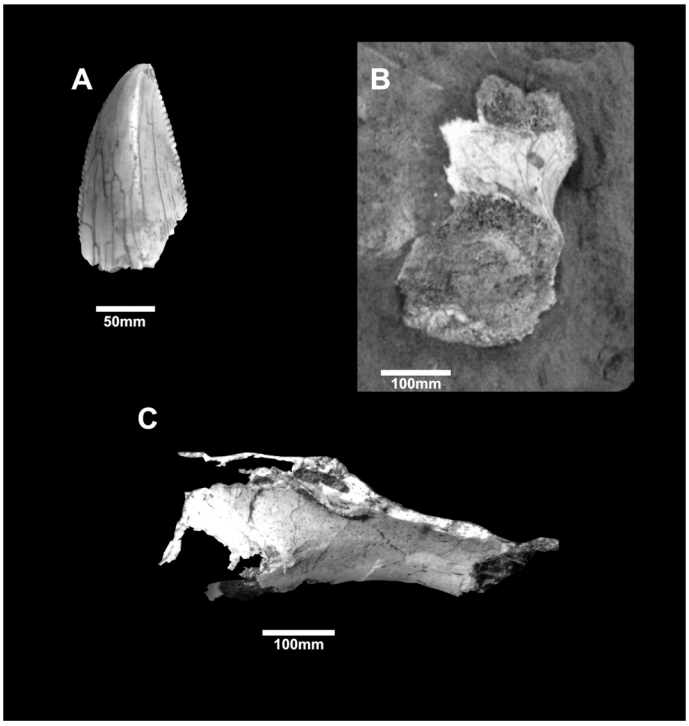

Figure 3: Late Cretaceous fossils of Adamantina Formation A – Tooth Abelisauroidea; B – Vertebra of the Crocodilomorpha; C, indeterminate bone of Crocodilomorpha.

Concluding remarks

The Bauru group is composed of sedimentary rocks containing abundant fossils; these rocks differin their modes of origin there by allowing the group to be divided into three formations: the Adamantina, Marília and Uberaba. Each of these units has its own peculiarities and characteristic colour and all have been deposited by water or wind.

The Adamantina formation has reddish coloured sandstone so it is easy to differentiate these rocks from other units; however, colour cannot always be assigned as a method for differentiating formations, as red-coloured rocks can also be founding the Marília formation. Other classification is required, such as grain-size thickness. Calcite was observed in the rocks in the sediments at the study sites and they had bioturbation marks on them.

The fossil fragments found were difficult to identify because they were damaged; however this is a good indication that the Campina Verde area promises to produce important new paleontological localities. This evidence already shows on going activity in that particular environment there by increasing interest in new, more detailed studies to improve scientific results achieved to date.

Although there are reports regarding some fossils discovered in Campina Verde, studies of the region are still few; new and more detailed research is necessary to allow better descriptions of geological and paleontological aspects.

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