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The first report of a Campanian palaeo-wildfire in the West Antarctic Peninsula

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ABSTRACT

The analysis of palaeofloras and the related palaeoecological conditions is of great importance for the understanding of past environmental and palaeoclimatic events in Antarctica. At the end of the Cretaceous, subtropical forests developed there because of wet and temperate climate conditions. On the Antarctic Peninsula, which is geologically characterized by a forearc context, volcanic activity caused by tectonics favours the ignition of vegetation fires. In the present study, the occurrence of palaeo-wildfires during the Upper Cretaceous is demonstrated for the Rip Point outcrop on Nelson Island, South Shetland Islands. During Brazilian expeditions to the area, macroscopic charcoal was collected and subsequently analysed under a stereomicroscope and scanning electron microscope (SEM). The charred wood remains were identified as belonging to conifers, which were important components of the Antarctic palaeoflora during the Cretaceous. A review of the data published thus far regarding palaeo-wildfires in the Southern Hemisphere confirms that the charcoal remains analysed here are the first to verify the occurrence of palaeo-wildfires in the upper Campanian levels of the West Antarctic Peninsula.

1. Introduction

Currently, Antarctica composes more than 10% of the total continental area of Earth, making it the fifth largest continent. The greatest portion of Antarctica has been maintained in the Antarctic Polar Circle since the end of the Mesozoic (Lavwer et al., 1991). The modern geographical design of Antarctica and the continents of the Southern Hemisphere have a common history that results from the gradual fragmentation of Gondwana (Tarling, 1988; Dalziel et al., 2000; Boger, 2011). In West Antarctica (WANT), or the Antarctic Peninsula, tectonic plate interactions and subduction processes have been taking place since the Early Mesozoic altering its geographical design during the time (Smellie et al., 1984; Del Valle and Rinaldi, 1993; Hervé et al., 2006).

The fossil record of WANT is distinguished from that of East Antarctica in that it comprises mostly Mesozoic and Cenozoic successions (Birkenmajer and Zastawniak, 1989; Yanbin, 1994; Cantrill and Poole, 2012; Reguero et al., 2013). As a result of the tectonic context and volcanism, the plant fossils of WANT were mostly preserved by sediments originating from fallen ash and surge deposits and the deposition of reworked volcanic grains produced during the breakup and convergence of tectonics plates (Birkenmajer, 2001; Willan and Hunter, 2005; Reguero et al., 2013).

Moreover, because plants are sensitive to climatic and environmental changes, fossiliferous successions are the most helpful for the reconstruction of climatic and ecological changes and events that occurred throughout geological time (Poole and Cantrill, 2006; Francis et al., 2008). One of the most readily preserved forms of the plant fossil record is macroscopic charcoal, which is the product of the incomplete combustion of plant biomass (Goldberg, 1985; Scott, 2010). Although macroscopic charcoal undergoes some shrinkage, resulting in subtle anatomical changes (Jones and Chaloner, 1991; Lupia, 1995), macroscopic charcoal preserves the anatomical and morphological details of fossils very well, and this information can be used in taxonomical and palaeoecological studies (Scott and Damblon, 2010).

Despite the volcanic context of WANT, which may have favoured palaeo-wildfires, studies regarding the macroscopic charcoal record in Antarctica are greatly lacking. For the Upper Cretaceous, only two localities (Eklund, 2003; Eklund et al., 2004; Kvaček and Sakala, 2011) with charred remains and structurally preserved fossil plants have been described in the literature.

Eklund (2003) and Eklund et al. (2004) described charred and structurally preserved plant remains found at the Table Nunatak Formation (Santonian), Kenyon Peninsula, Antarctic Peninsula Eastern margin. Additionally, Kvaček and Sakala (2011) cited the occurrence of charcoalified

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plant mesofossils from the Hidden Lake and Santa Marta Formations (Coniacian/Campanian), James Ross Island; however, they did not provide detailed analyses of those charcoal remains.

Brown et al. (2012) reviewed the occurrence of Cretaceous palaeo-wildfires on a global scale, only citing the two records by Eklund (2003) and Eklund et al. (2004) for Antarctica. Although the authors illustrated a charcoal assemblage with charred angiosperm reproductive organs for the Antarctic Campanian/Maastrichtian interval on a schematic map (see Brown et al., 2012 — fig. 3c), the references for that occurrence could not be found in that paper.

According to Scott et al. (2014), after the Permian–Triassic boundary fire systems collapsed, which resulted in a reduction of palaeo-wildfire records during the Triassic and Jurassic, the Cretaceous can be considered as a "high-fire" world. However, while charcoal from the Cretaceous period has been extensively described for Eurasian areas (Brown et al., 2012) direct palaeo-wildfire evidence records [charcoal, inertinites in coals or pyrogenic polycyclic aromatic hydrocarbons (PHAs)] for the entirety of Gondwana are scarce (Eklund et al., 2004; Brown et al., 2012).

With that information gap in mind, each new discovery of Cretaceous palaeo-wildfire evidence contributes to the construction of a Cretaceous palaeo-wildfire scenario for Gondwana. In that regard, the present paper reports the first detailed analysis of macroscopic charcoal from the north-western sector of the Antarctic Peninsula and the second analysis of macroscopic charcoal from the Campanian period for all of Antarctica. The charcoal was detected amongst non-charred wood fragments preserved in the basal tuff levels of the volcanoclastic succession exposed at the Rip Point, northeast Nelson Island (Fig. 1).

2. Geological and palaeontological context

Past geological processes are preserved and can be detected in the fossil record from the Lower to Upper Palaeozoic successions from East Antarctica (Bose et al., 1990; Taylor and Taylor, 1990; McLoughlin et al., 1997; Dutra and Jasper, 2010). In WANT areas, the Mesozoic and Cenozoic events are attested (e.g. Dutra, 2004; Cantrill and Poole, 2012; Reguero et al., 2013).

The western South Shetland and Alexander Islands to the West and the eastern James Ross Basin contain a well-known fossil record from the Antarctic Peninsula that consists mainly of plants, vertebrates and various invertebrate groups. Starting from the Jurassic (with uncertain Triassic levels), the fossiliferous succession extends to the upper Miocene, when the ice cover of this sector affected a large area (Falcon-Lang and Cantrill, 2000; Yanbin, 1994; Birkenmajer, 2001; Dutra, 2004; Cantrill and Poole, 2012; Reguero et al., 2013).

Nelson Island, where the material discussed here was collected, is one of the northernmost islands of the South Shetland Island archipelago. It is composed of insular fragments of volcanic origin and was formed in a forearc context at the western margin of the Antarctic Peninsula. The geologic and structural constraints of WANT indicate the influence during the Mesozoic of the subduction process of western Pacific. After the end of Paleogene, by the strike-slip fault systems that result in the drifting apart of the of the South America and the Antarctic Peninsula (Adie, 1964, 1977; Barton, 1965; Birkenmajer, 1981, 2001; Smellie et al., 1984, 2006; Elliot and Fleming, 2000; Hervé et al., 2006).

Like the other South Shetland Islands, Nelson Island is mainly composed of andesitic and intrusive lavas, with a few thin intercalations of volcanoclastic sediments (Elliot, 1988; Birkenmajer, 2001). Palaeontological surveys have shown that the fossiliferous levels are restricted to the northeast part of the Island and occur in an isolated outcrop at Rip Point on the Fildes Strait coast approximately 1.0 km north of the Crulls Brazilian Refuge (62°14′19"S/58°59′0"W). The exposure begins near sea level and extends nearly 10.0 m high. Geological prospecting in the area has shown that similar, but less well-preserved, fossils and intercalations of lava and tuff also occur in levels at an altitude of 200.0 m (Birkenmajer, 1981; Hansen et al., 1988). The Fildes Strait separates Nelson Island from southern King George Island, in which other Upper Cretaceous lithologies are exposed [e.g. Half Three Point (Liu, 1990)]. According to Birkenmajer (1981), the Fildes Strait resulted in faults transversally positioned in relation to the alignment of the South Shetland Islands.

The Rip Point outcrop is composed of dark grey pyroclastic rocks and lavas (tuff and lapilli) with restricted lenses of volcanoclastic grains. Macro- and microfloristic records occur in two horizons (Fig. 2). The

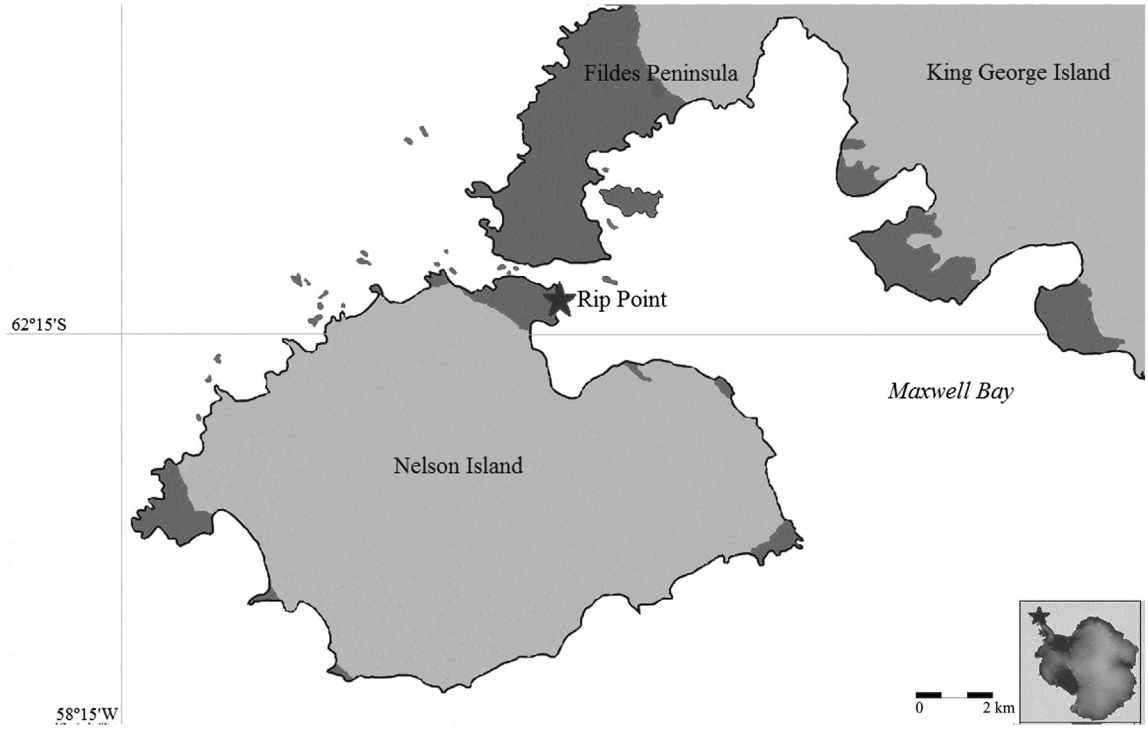

Fig. 1. Simplified map of Antarctica with the position of Nelson Island in relation to the Antarctic Peninsula. The Rip Point locality is indicated by the star on Nelson Island.