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Stratigraphy, sedimentology and paleontology of Upper Cretaceous deposits of Day Nunatak, Snow Hill Island, Antarctica

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ABSTRACT

Day Nunatak exposes an actively emergent stratigraphic section located on Snow Hill Island to the east of the Antarctic Peninsula. Strata exposed on Snow Hill Island were deposited in the James Ross Basin, which includes marine units of Cretaceous–Paleogene (K–Pg) age. Here we provide the first report of the sedimentology and paleontology of Day Nunatak, and place it into the broader stratigraphic context of the basin. Day Nunatak was previously unexplored due to difficulties accessing the site, and the historically poor exposure which has recently improved due to warming of the Antarctic Peninsula. Deposits exposed at Day Nunatak are assigned to the Karlsen Cliffs Member (KCM) of the Snow Hill Island Formation, and are better preserved than deposits at the type section of the KCM at Karlsen Cliffs, which has been altered by cross-cutting basaltic dikes. Correlation of lithostratigraphic and biostratigraphic data from Day Nunatak with other outcrops in the basin allows the section to be placed within a previously developed stratigraphic framework, and assigned an early Maastrichtian age. Our observations, and previous descriptions of the KCM, are consistent with a middle- to inner-shelf depositional environment below storm-wave base. Ammonites of the genus *Gunnarites* are very common, with other ammonite genera and benthic mollusks an order of magnitude less common. Stable carbon and oxygen isotope values obtained from bivalve shells are similar to values previously reported from Seymour Island, and suggest seawater temperatures of ~7 °C. Measured bedding orientations suggest the presence of a structural offset between Day Nunatak and other sections exposed further north on Snow Hill Island. Day Nunatak preserves a similar depositional environment to deposits reported from the uppermost Maastrichtian on Seymour Island, and is the deeper-water equivalent of contemporaneous proximal sections reported from Vega Island.

1. Introduction

The Late Cretaceous record from Antarctica is represented primarily by sedimentary rocks deposited in the James Ross Basin (JRB). These rocks crop out throughout the James Ross Island archipelago, which is located on the eastern side of the Antarctic Peninsula (Fig. 1). JRB sediments are only exposed in areas where snow and/or ice cover does not persist over the austral summer, which limits exposure in many areas of the archipelago. There are several continuous stratigraphic exposures located on the comparatively well-studied James Ross Island (Crame et al., 1991; Olivero, 1992; Strelin et al., 1992) and Seymour Island (Macellari, 1988; Zinsmeister, 2001; Olivero et al., 2007; Tobin et al., 2012; Witts et al., 2016; Tobin, 2017) which contain abundant and well-preserved invertebrate fossils and a well exposed Cretaceous–Paleogene (K–Pg) boundary. The smaller islands of the archipelago, including Vega, Snow Hill, Cockburn, and Humps, as well as geographically-isolated smaller exposures on the eastern and southern shores of James Ross Island, are either more difficult to access, limited in areal extent, or both. As a consequence, these locations are not as well studied and their stratigraphic positions relative to the rest of the basin are not as well-constrained (Olivero, 2012; Roberts et al., 2014).

Here we report the first paleontological and sedimentological description of the Cretaceous sediments exposed at Day Nunatak, Snow Hill Island, based on our observations made during

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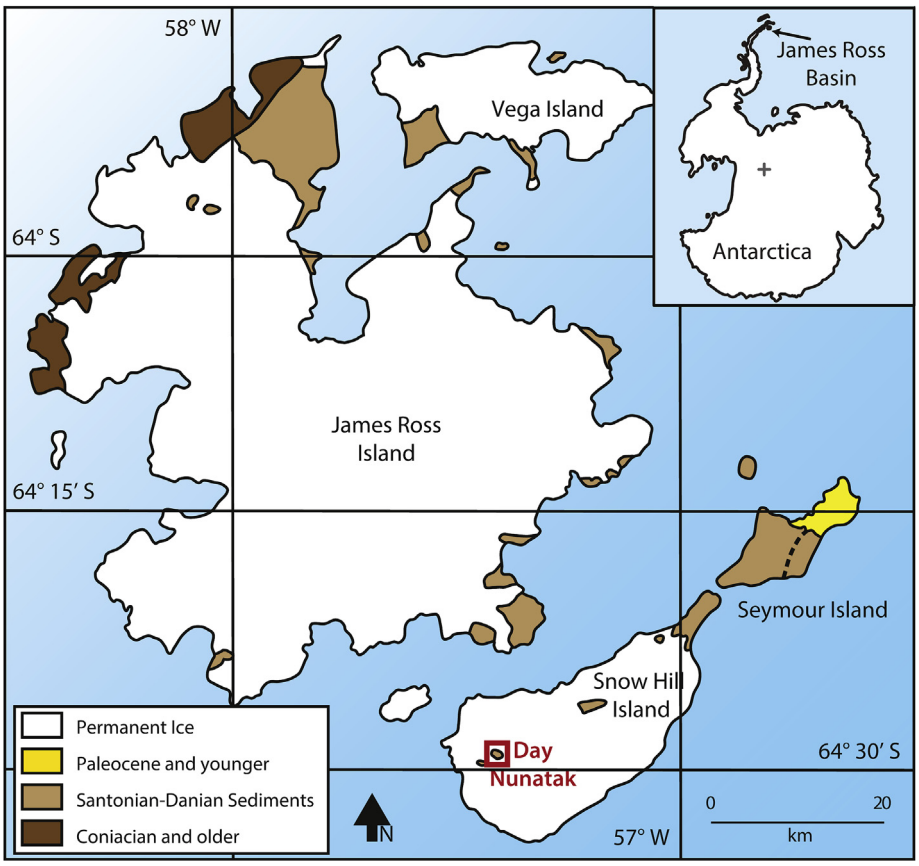

Fig. 1. Map of the James Ross archipelago showing its location relative to the Antarctic continent (inset). The red box indicates the location of Day Nunatak (see Fig. 2). After Crame et al. (2004). (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

exploration in March 2016. Day Nunatak was named in 1995 by the United Kingdom Antarctic Place Names Committee and was first mentioned in the geologic literature by Pirrie et al. (1997). The minimal prior investigation of this locality is a consequence of both the inaccessibility and relatively recent exposure. Day Nunatak is surrounded by heavily crevassed glacial ice, restricting access to helicopter flights. The outcrop was exposed recently, probably as a result of warming during the last 50 years. Fig. 2 shows Landsat imagery of the area from 1975 to present, where the earliest available satellite imagery, though low resolution, shows minimal exposure. Fig. 3 documents the increase in the exposed area of Day Nunatak as measured from nine Landsat images spanning the years 1975–2017. Increased exposure due to receding ice has created landing sites for helicopters, unvisited sedimentary outcrops, and extensive fossils weathered from the poorly lithified sediment. This report describes the sedimentology and paleontology of Day Nunatak, places the section within the sequence stratigraphic context of the JRB, and presents a three-dimensional model of the locality using structure from motion computational techniques applied to low-altitude imagery (Fig. S1).

2. Geologic setting

The JRB is composed primarily of sediments dated from the Aptian (~125 Ma) through the Eocene (~34 Ma) (Crame et al., 2006; Ivany et al., 2006; Marenssi et al., 2002; Olivero, 1992, 2012), locally capped Neogene volcanics and Quaternary glacial sediments (Smellie et al., 2008). JRB sediments were deposited in the rapidly subsiding back arc associated with Cretaceous uplift of the Antarctic Peninsula. Minimal metamorphism, alteration, and tectonic movement or deformation has occurred since deposition. Most of the stratigraphic thickness of the basin consists of Santonian–Danian (~85–65 Ma) deposits of the Marambio Group, which has been the focus of most previous work. Olivero (2012) presented a detailed sequence stratigraphic model for the JRB wherein the Marambio Group is divided into three sequences, with the proximal basin deposits to the west (closer to the Antarctic Peninsula) and the distal basin deposits to the east. The Marambio Group is typically interpreted as prograding shelf facies, with a shoreline and center of deposition migrating toward the east.

The Marambio Group is composed (oldest to youngest) of the Santa Marta, Snow Hill Island, López de Bertodano, and Sobral formations, although this stratigraphic nomenclature has been used inconsistently. In particular, the Haslum Crag Sandstone has sometimes been elevated to a formation (adopted here) between the Snow Hill Island and López de Bertodano formations (Olivero et al., 2008; Olivero, 2012) or demoted to the uppermost member of the Snow Hill Island Formation (SHIF) (Crame et al., 2004; Roberts et al., 2014). In the southern and eastern parts of the JRB, the SHIF is composed (oldest to youngest) of the Hamilton Point, Sanctuary Cliffs, and Karlsen Cliffs members (KCM), as well as (in some descriptions) the Haslum Crag Member. In the more proximal part of the basin to the west, the SHIF is comprised of the Upper and Lower Cape Lamb members, which are age equivalent to the members on Snow Hill Island (Roberts et al., 2014). Based on the evidence presented below, we suggest the Cretaceous deposits of Day Nunatak should be considered part of the KCM (Fig. 4).