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Seven million year history of the Antarctic Peninsula Ice Sheet revealed by coupled geological and climate modelling studies

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A coupled geological—climate modelling study has been used to infer the configuration of the Antarctic Peninsula Ice Sheet (APIS), for the period between c. 7 Ma and present, principally using information derived from volcanic outcrops scattered along the length of the Antarctic Peninsula. The volcanism is exclusively basaltic and varies from multiple monogenetic volcanic fields to large stratovolcanoes. Practically all the outcrops are glaciovolcanic, i.e. the rocks were erupted in association with a coeval ice sheet. Glaciovolcanic studies have advanced substantially over the past 10 years through increasingly detailed process-orientated outcrop investigations linked to observations of modern eruptions. They are slowly becoming established as an important ice sheet proxy tool capable of yielding the widest and most precise range of critical ice sheet parameters of any terrestrial proxy. They are particularly important for pre-LGM periods, when most other terrestrial proxies typically get erased or cannot be dated. Conversely, the generally low frequency of volcanic eruptions precludes any Milankovitch-scale cyclicity being identified. Additionally, the precision of K-Ar and 40Ar/39Ar dating of young basaltic lavas in the region is relatively poor compared with the duration of glacial—interglacial periods and any relationship in timing between eruptions and the corresponding stage in any glacial cycle, cannot be demonstrated. Despite these drawbacks, the results of the study have yielded unique environmental information that demonstrate the usefulness of glaciovolcanismas a terrestrial proxy tool in multidisciplinary palaeoenvironmental investigations. The eruptions took place when the Antarctic Peninsula Ice Sheet (APIS) was relatively thin, typically less than c. 400 m and never thicker than c. 900 m. The APIS also apparently increased in thickness toward the present mirroring the trend to colder temperatures globally. It was wet-based and erosive throughout the period, although information younger than 1 Ma is sparse. Thus it had a temperate or, perhaps more likely, sub-polar thermal regime with no obvious transition to polar ice at 3 Ma that has been suggested by others. It must also have had a low profile. Estimated net snow accumulation was derived from numerical palaeoclimate model experiments using a wide range of warm Pliocene boundary conditions. The results are consistent with the geological information and indicate that an ice sheet existed during the period, and there is some evidence that it was persistent during all conditions of Pliocene warmth tested. Overall the model simulations suggest the potential existence of an APIS over a global mean temperature change spanning from +1.9 to +4.5 degs C. Thus, an unanticipated and counter-intuitive conclusion of our study is that, although the APIS may always have been relatively thin during its existence, it might also be a more robust feature than is generally assumed, at least within the range of climatic conditions examined in our study.