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Cenozoic extension along the reactivated Aurora Fault System in the East Antarctic Craton

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A B S T R A C T

The East Antarctic Craton is characterized by major intracontinental basins and highlands buried under the 34 Ma East Antarctic Ice Sheet. Their formation remains a major open question. Paleozoic to Cenozoic intraplate extensional tectonic activity has been proposed for their development and in this work the latter hypothesis is supported. Here we focus on the Aurora Trench (AT) within the Aurora Subglacial Basin (latitude 75°–77°S, longitude 117°–118°E) whose origin is still poorly constrained. The AT is an over 150-km-long, 25-km-wide subglacial trough, elongated in the NNW-SSE direction. Geophysical campaigns allowed better definition of the AT physiography showing typical half-graben geometry. The rounded morphology of the western flank of the AT was simulated through tectonic numerical modelling. We consider the subglacial landscape to primarily reflect the locally preserved relict morphology of the tectonic processes affecting the interior of East Antarctica in the Cenozoic. The bedrock morphology was replicated through the activity of the listric Aurora Trench Fault, characterized by a basal detachment at 34 km (considered the base of the crust according to available geophysical interpretations) and vertical displacements ranging between 700 and 300 m. The predicted displacement is interpreted as the (partial) reactivation of a weaker zone along a major Precambrian crustal-scale tectonic boundary. We propose that the Aurora Trench Fault is the southern continuation of the >1000 km long Aurora Fault independently recognized by previous studies. Together they form the Aurora Fault System, a long lived tectonic boundary with poly-phased tectonic history within the EAC that bounds the eastern side of the Aurora Subglacial Basin. The younger Cenozoic reactivation of the investigated segment of the Aurora Fault System relates to the intraplate propagation of far-field stresses associated to the plate-scale kinematics in the Southern Ocean.

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1. Introduction

The interior of East Antarctica is characterized by the presence of the 34 Ma East Antarctic Ice Sheet (EAIS; Barrett, 1996; De Conto and Pollard, 2003) covering almost completely the continent. Sparse outcrops and geophysical data collected in the last decades (Aitken et al., 2014; An et al., 2015; Fretwell et al., 2013; Ferraccioli et al., 2011; Ferraccioli et al., 2009; Jordan et al., 2013; Tabacco et al., 2006, Popov et al., 2007; Studinger et al., 2004), support the present day uncomplete knowledge on the subglacial geology that leaves several unanswered questions and open debates on its tectonic and geodynamic setting.

East Antarctica is a Precambrian Craton (EAC) that recorded the assembly and breakup of early supercontinents since Precambrian times (e.g. Torsvik, 2003; Boger, 2011; Dalziel, 2013; Harley et al., 2013; Fitzsimons, 2000; Aitken et al., 2016a; Phillips and Läufer, 2009). A large interval of the Mesozoic and Cenozoic geological history of Antarctica is mainly dominated by the break-up of Gondwana, and by its movement towards the present polar location. The last tectonic history includes intraplate Permian-Cretaceous age rifting and transtension associated with the East Antarctic Rift System (Ferraccioli et al., 2011), shearing along the Indo-Australo-Antarctic Suture (IAAS; Aitken et al., 2014; Aitken et al., 2016a), development of the Wilkes Subglacial Basin (Ferraccioli et al., 2001; Ferraccioli et al., 2009; Jordan et al., 2013), uplift of the Transantarctic Mountains, and Cenozoic tectonics and magmatism (Stern and ten Brink, 1989; Salvini et al., 1997; Tonarini et al., 1997; Cande et al., 2000; Fitzgerald, 2002; Rossetti et al., 2003).

The Antarctic plate is presently characterized by a unique geodynamic setting since it is almost completely surrounded by divergent or conservative margins (spreading ridges and major transforms), with the exception of the limited subduction zones of South Sandwich and South Shetland Islands/Ross Peninsula (e.g. Fig. 1a in Cianfarra and Salvini, 2016a). This tectonic setting accounts for the present day clockwise rotation of the Antarctic plate within the absolute velocity

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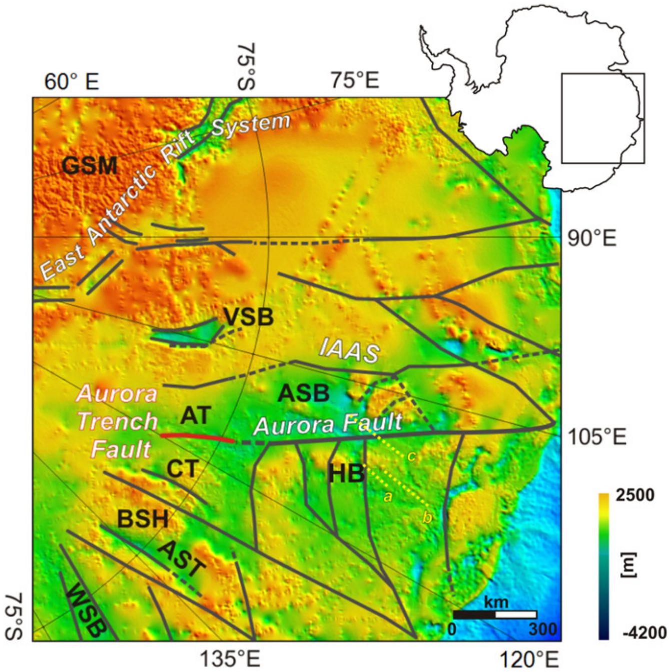

Fig. 1. Subglacial topography map of the central part of East Antarctic Craton from Bedmap-2 dataset (Fretwell et al., 2013) with the main bedrock physiographic features and location map. Dark grey lines are proposed faults, dashed when inferred, from Ferraccioli et al., 2011, Aitken et al., 2014 and Cianfarra and Salvini, 2016a. The red line is the Aurora Trench Fault. Yellow dashed lines indicate the location of the HiCars2 profiles in Fig. 4 with the same labelling. Legend: GSM: Gamburtsev Subglacial Mts; VSB: Vostok Subglacial Basin; ASB: Aurora Subglacial Basin; AT: Aurora Trench; CT: Concordia Trench; BSH: Belgica Subglacial Basin; AST: Adventure Subglacial Trench; WSB: Wilkes Subglacial Basin; HB: Highlands B; *IAAS*: Indo-Australo-Antarctic Suture.

reference frame (Dubbini et al., 2010) and for the low level of intracontinental seismicity (Reading, 2007). According to classical plate tectonics the described setting prevents crustal deformation in the interior of EAC (Cande and Stock, 2004; Müller et al., 2000; An et al., 2015). Nevertheless, a series of fault-controlled, regionally-sized bedrock depressions (hosting sedimentary basins) and mountain ranges characterize the EAC (Studinger et al., 2003; Studinger et al., 2004; Bell et al., 2006; Phillips and Läufer, 2009; Ferraccioli et al., 2009; Ferraccioli et al., 2011; Jordan et al., 2013; Fretwell et al., 2013; Aitken et al., 2014, Cianfarra et al., 2003, 2009; Cianfarra and Salvini, 2003, 2016a) and their presence in the subglacial bedrock is also visible on EAIS surface as revealed from satellite images (Cianfarra and Salvini, 2014; Cianfarra and Salvini, 2016a; Jamieson et al., 2016). The Aurora Subglacial Basin and the Vostok Subglacial Basin (ASB and VSB) are the most prominent subglacial topographic features in the central part of the EAC (Fig. 1) with along-strike dimensions of the order of hundreds to thousands of kilometers and up to 10 km thick sedimentary infill (Studinger et al., 2003; Ferraccioli et al., 2011; Aitken et al., 2014). The Aurora Trench (AT) is a subglacial trough within the ASB (Tabacco et al., 2006). To date several models have been forward to explain the origin of these intraplate basins. Studinger et al. (2003) interpreted gravity and magnetic anomaly data in the region of VSB to represent a suture zone characterized by an East-dipping thrust active in Proterozoic times. A minor extensional reactivation of the basal thrust fault created the space for the present-day Lake Vostok. Ferraccioli et al. (2011) frame the VSB within a belt of eastward stepping rifts forming the East Antarctic Rift System that was active during the Paleozoic to Mesozoic continental rifting and intraplate strike-slip faulting. This rift system partly developed on a Proterozoic foreland sedimentary basin, with geometry similar to the East African Rift System. Today the basins of this rift system host the largest Antarctic subglacial lakes, namely Lake Vostok, Lake Sovetskaya, Lake 90° and Recovery Lake (Bell et al., 2007). On the basis of new geophysical data (magnetic, gravity, and ice penetrating radar data) Aitken et al. (2014) identified the >1000 km long Aurora Fault bounding the present day eastern side of the ASB that is characterized by over 5 km thick sedimentary infill. This fault represents a major tectonic boundary within EAC characterized by a long-lived, poly-phased tectonic history since Precambrian times. The Aurora Fault played a primary role in the assembly and break-up of the Columbia and Rodinia supercontinents in Proterozoic times through hundreds of kilometers of strike-slip motion (Aitken et al., 2014; 2016a). The lack of available geophysical data does not allow constraining the present day southward continuation of the Aurora Fault within the EAC.

The Paleozoic to Mesozoic reactivation of the Aurora Fault relates to the shearing associated to the nearby Indo-Australo-Antarctic suture, to the East Antarctic Rift System (Ferraccioli et al., 2011) and its subsidiary intraplate fault systems including the Vostok Fault (Studinger et al., 2003; Cianfarra and Salvini, 2013), and faults bounding the basins surrounding the Gamburtsev Subglacial Mts. and the Knox Rift. This tectonic history relates to the break-up between India and East Antarctica (Ferraccioli et al., 2011; Aitken et al., 2014). More recently, Cianfarra and Salvini (2016a) described the Cenozoic extensional tectonic origin of the Adventure Subglacial Trench (AST) and framed the Adventure Fault into a regional transpressional corridor running regionally E-W from the foothills of the GSM to the AST as the intraplate propagation of far field stresses associated to the plate kinematics in the Southern Ocean.

Most of the tectonic-related depressions in the EAC, and specifically Vostok, Aurora, Concordia, and Adventure, are characterized by a strong asymmetry of their slopes that can easily be explained with a substantial contribution of the activity of listric normal faults (Tabacco et al., 2006; Cianfarra et al., 2009; Cianfarra and Salvini, 2013; Cianfarra and Salvini, 2016a).

The aim of this paper is to provide new clues on the possible tectonic setting of the Aurora Trench to better constrain the southward projection of the Aurora Fault at latitudes between 75° and 77° S. We present the results of the tectonic modelling of 6 airborne Radio Echo-Sounding (RES) profiles across the AT, collected in the framework of PNRA (Programma Nazionale di Ricerche in Antartide, Italian National Antarctic Research Program) expeditions, which allowed reconstructing the 3D geometry of the Aurora Trench listric Fault responsible for the formation of Aurora Trench.

2. Geological setting of the Aurora Trench

The investigated area is located in the central part of East Antarctica, in the Vostok-Dome C region where a cluster of about 50 subglacial lakes exists including Vostok, the largest one, Concordia, and Aurora lakes (Siegert et al., 2005, Kapista et al., 1996; Tabacco et al., 2002; Wright and Siegert, 2012). The subglacial geology of this sector of East Antarctica has been investigated in the last decades by a number of international geophysical campaigns (e.g. Studinger et al., 2003; Studinger et al., 2004; Tabacco et al., 2006; Popov et al., 2007; Ferraccioli et al., 2009; Ferraccioli et al., 2011; Jordan et al., 2013; Aitken et al., 2014; An et al., 2015; Urbini et al., 2015). A total of 18,500 km RES data were collected during the PNRA expeditions from 1995 to 2003 in the Vostok-Dome C region (Tabacco et al., 1998, 2002; Forieri et al., 2004, 2008). Radar data were collected with the INGV-IT radar instrumentation (Tabacco et al., 1999; Zirizzotti et al., 2008), which is characterized by a 3.5 kW power envelope system, an operating frequency of 60 MHz, a vertical resolution of 1280 samples, a sampling frequency of 20 MHz and a variable pulse length (from 0.2 to 1 μs). Data filtering, analyses and ice thickness calculations were performed following the same procedures as described in Tabacco et al. (2006) and Cianfarra et al. (2009).

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