A Cretaceous Victoria Basin between Australia and Antarctica inferred from volcanoclastic deposits, thermal indications and thermochronological data

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Summary The analysis of numerous apatite fission track (AFT) data sets throughout the Transantarctic Mountains reveals three episodes of upper crustal cooling since the Cretaceous. Traditional thinking presumes that this cooling was produced by uplift and denudation stages occurring in the Early Cretaceous, the Late Cretaceous, and the Cenozoic. However, diachronous paleotemperatures up to 400°C determined on Jurassic superficial rocks require substantial burial and thermal activity before a stable geothermal gradient was established during the Late Cretaceous. Therefore, an extensive sedimentary basin between Antarctica and Australia must have existed, likely due to continental rifting processes leading to Gondwana breakup and passive margin formation. Denudation-dominated cooling occurred only with the formation of the Cenozoic West Antarctic Rift System and the related uplift of the Transantarctic Mountains since ca. 55 Ma.

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Introduction

The present concept of the Phanerozoic long-term landscape evolution of the western Ross Sea region (Antarctica) relies on the formation of an extensive Beacon Basin between the Devonian and the Triassic, followed by the emplacement of mafic magmatic rocks (Ferrar Dolerites and Kirkpatrick Basalts) at ~180 Ma. The post-Jurassic regional tectonic history is not recorded by petrological or stratigraphic evidence and, therefore, depends chiefly on apatite fission track (AFT) data. Numerous AFT ages from various locations along the whole Transantarctic Mountains scatter between ~30 and ~350 Ma, with the vast majority being younger than 130 Ma. The analyzed vertical AFT age profiles include at least one distinctive break in slope at ~50 Ma (summarized by Fitzgerald, 2002, and Lisker, 2002). The AFT data are interpreted in terms of three discrete cooling stages during the Early Cretaceous, Late Cretaceous, and Cenozoic and have been related to regional denudation events associated with: (i) the initial break-up between Australia and Antarctica, (ii) the extension between East and West Antarctica along low-angle extensional faults; and (iii) the formation of the Cenozoic West Antarctic Rift System triggering the uplift of the Transantarctic Mountains (cf. Fitzgerald, 2002). Thereby, all previous AFT studies explicitly or implicitly presume that the overburden removed since the Early Cretaceous consisted of predominantly Beacon sedimentary rocks of Devonian – Triassic age possibly including some Ferrar rocks (e.g., Fitzgerald, 1994, 2002; Balestrieri and Bigazzi, 2001). This assumption appears justified since remnants of the Beacon Supergroup are preserved across the whole Transantarctic Mountains below Ferrar sills that are supposed to have intruded this formerly much thicker sequence. This traditional interpretation is well in agreement with structural and geophysical data and seems to be consistent for the majority of the sampled AFT locations when considered separately. However, the stratigraphic position of the youngest Beacon strata and the emplacement level of the Ferrar rocks are in rigorous contrast to the established interpretation of the AFT data.

Discussion

Many of the studied vertical AFT profiles along the whole Transantarctic Mountains or their immediate surroundings are unconformably overlain by the youngest Beacon members consisting of Late Triassic to Middle Jurassic pyroclastic and siliciclastic, partially fossil-bearing sequences (e.g., Elliot, 2000). The nature of these sediments in context with their integration within the process of Ferrar emplacement require that the presently preserved Ferrar sills must have been intruded in a very shallow level, similar to the equivalent, subaerial Kirkpatrick Basalt flows.

On the other hand, numerous Ar/Ar, K-Ar, and Rb-Sr ages of Ferrar Dolerites, ages of geomagnetic paleopole positions and assemblages of secondary minerals (compiled by Molzahn et al., 1999), AFT data (compiled by Fitzgerald, 2002; Lisker, 2002), diagenetic indications (Ballance and Watters, 2002; Bernet and Gaupp, 2005), and epidote coatings on fault planes (observed recently by the authors) imply post-Mid-Jurassic to Late Cretaceous maximum paleotemperatures between ~80° and 400°C (Fogure 1), with temperatures >150°C being restricted to the vicinity of northern Victoria Land. It is crucial to note that these elevated palaeotemperatures were reached diachronously, with discrete heating events reported at the beginning of the Early and Late Cretaceous, respectively (e.g., Molzahn et al., 1999).

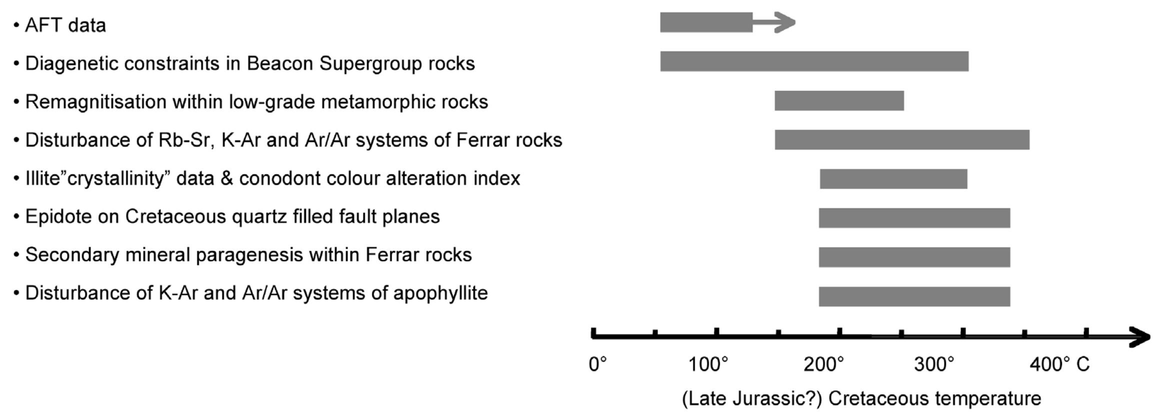

Figure 1. Jurassic – Cretaceous paleotemperature indications from northern Victoria Land (data compiled after Molzahn et al., 1999; Fitzgerald, 2002; Lisker, 2002; Ballance and Watters, 2002; Bernet and Gaupp, 2005). Note that these temperatures were reached diachronously between Middle Jurassic and Late Cretaceous times.

Of particular significance is a series of vertical AFT profiles with ages between ~40 and ~280 Ma from the region around the Priestley Glacier (northern Victoria Land), sampled from granitic basement rocks immediately beneath a Jurassic basaltic flow comprising volcanoclastic beds (Balestrieri et al., 1999). All ages from samples above a break in slope at ~40 Ma show a very flat and uniform regression with the topographic altitude. Since the AFT age pattern of the basement below the superficial Jurassic flow is not disturbed by any Ferrar age signature (i.e., a ~180 Ma age component), the whole sample suite must have resided for some time at higher PAZ temperatures (i.e., ~80° – 110°C) after the Ferrar event.

Towards the end of the Cretaceous, indications on temperatures significantly exceeding the AFT thermochronometer vanish. This decline towards relatively low and homogeneous temperatures correlates with the establishment of a geothermal gradient of approximately 25°C/km (Lisker et al., 2006).

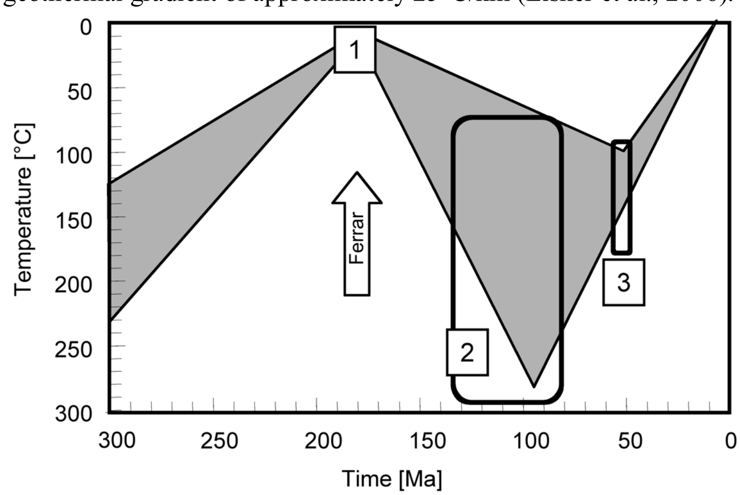

Figure 2. Spectra of t-T-paths for rocks of the Ferrar emplacement level within northern Victoria Land (grey contour). The marked t-T envelopes refer to: [1] the Ferrar emplacement at surface level, [2] burial accompanied by extremely varying heatflow during the Late Jurassic-Cretaceous (cf. text), and [3] maximum burial depths between ~3 and 5 km as concluded from a Late Cretaceous/Cenozoic geothermal gradient of ~25°C/km (Fitzgerald, 1994; Lisker et al., 2006).

The geological and thermal indications listed here provide three reliable time-temperature envelopes for the Ferrar surface levels cropping out now at similar elevations within the whole Transantarctic Mountains: (1) surface temperature during the Middle Jurassic, (2) subsequent, diachronously (180 – 100 Ma) varying temperatures between ~80° and 350°C, and (3) Late Cretaceous/Early Cenozoic temperatures of ~80° – 150°C (Fogure 2). Considering the geothermal gradient of 25°C/km, the Ferrar surfaces had to be buried from Mid-Jurassic surface level to Late Cretaceous depths of ~3 to >5 km. The lack of any tectonic displacement or thermal trend suggests that significantly higher and extremely varying temperatures (at different times!) can be explained solely by varying heatflow within a sedimentary basin with sedimentary thicknesses probably not exceeding the Late Cretaceous maximum depths. The existence of such a Mid-Jurassic – Cretaceous "Victoria Basin" is strongly supported by the geological situation of the juxtaposed Australian passive margin that is characterized by the presence of a series of major, contemporaneous rift basins, with Eyre Sub-basin, Great Australian Bight, Duntroon Basin and Bight/ Otway/ Gippsland Basin being the most important ones. Late Jurassic – Cretaceous rifting in the Otway Basin opposite northern Victoria Land was accompanied by rapid subsidence and basin-wide deposition of the typically 3 – 5-km thick Otway Supergroup, with correlative units also deposited in the Bass and Gippsland Basins. The SE Australian basins still contain an up to 15 km thick, predominantly Jurassic and Early Cretaceous sedimentary sequence deposited on continental crust (e.g., Willcox and Stagg, 1990). Moreover, the Otway Basin experienced a variably increased Cretaceous geothermal gradient up to 70°C/km (Mitchell, 1997), and the respective AFT patterns of both the northern Victoria Land and the SE Australian margins indicate very similar timing and amounts of denudation (e.g., Moore et al., 1986; Lisker et al., 2002).

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