Continental transform faults: Break-up examples from the Antarctic and the Arctic

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Summary Continental transform faults, e.g. San Andreas Fault or Dead Sea transform, link plate boundaries by traversing continental crust. Other continental transforms existed in the past, but were later modified into oceanic spreading features. The sinistral Balleny transform system between Tasmania and Ross Sea is such a complex in the Antarctic. In the Arctic, the comparable dextral de Geer fault system separated Spitsbergen from Greenland. Cenozoic fold-and-thrust-belts were taken as related onshore features. This relation, however could be ruled out later in corresponding North Greenland. Therefore no clear onshore effects of the transform remain today. In the Antarctic on the contrary, there is a possibly related set of faults in North Victoria Land (NVL). However, these faults are dextral in character and differ therefore from the "cumulative" sinistral offset between Tasmania and Victoria Land.

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Introduction

There is no such thing as bipolar geology. Both polar regions are fundamentally different, the Antarctic forming a major continental plate covered by inland ice and the Arctic having a deep ocean in the centre covered by sea ice. Still, both areas are affected by the present plate tectonic cycle which is responsible for the break-up of Gondwana in the south and the break-up of Laurasia in the north. Therefore it is not surprising to find comparable geodynamic features in both polar areas.

The Balleny system between Australia and Antarctica

In plate tectonics, fracture zones are an oceanic feature related to the offset of a mid-oceanic ridge. All observations indicate that they terminate at the ocean/continent boundary, i.e. at the foot of the continental rise. There has been, however, the recent suggestion, that fracture zones between the Southeast Pacific and the Southeast Indian Ocean continue onshore in Antarctica across NVL (Rosetti et al., 2002; Roland and Damaske, 2006).

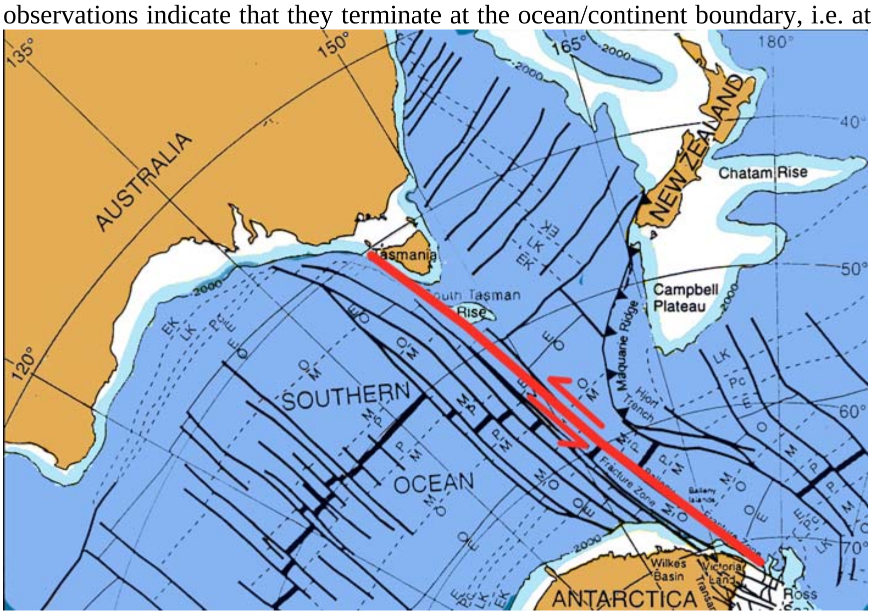

Figure 1. The Balleny Transform System between Tasmania and Ross Sea links the mid-oceanic ridge sytems of the Southeast Indian and the Southeast Pacific Oceans. The sinistral offset is more than 3000 km. The opening between Australia and Antarctica started in the Cretaceous, the remaining landbridge between Tasmania and Victoria Land was broken up much later in mid-Tertiary time.

Contrary to fracture zones, transform faults between plate boundaries may pass through continental crust. Well known examples are the San Andreas Fault of California, the Alpine Fault of New Zealand and the Dead Sea Transform of the Arabian Peninsula.

A similar setting may have existed between Tasmania and the Ross Sea (Fig. 1). There is a cumulative sinistral offset of several thousand km between the two mid-oceanic ridges. The spreading history of the Southeast Indian Ocean between Australia and Antarctica indicates that although spreading started in the Cretaceous, the connection to the Southeast Pacific did not break through until mid-Tertiary (Lawver and Gahagan, 1994).

There is evidence in the oceanic anomaly pattern, in the shape of the continental margins and in onshore faults in Victoria Land and Tasmania that Australia and Antarctica remained connected in this area until the Eocene. It seems probable that a sinistral transform system was developed through this continental bridge. This would explain the rather peculiar parallelism between onshore and offshore structures in NVL, one set in oceanic crust, another one onshore in continental crust. It may, however, be useful to compare this case with a similar plate setting in the Arctic, particularly, as Campbell Craddock has actively studied this case (Craddock et al., 1985).

De Geer Fault between Greenland and Spitsbergen

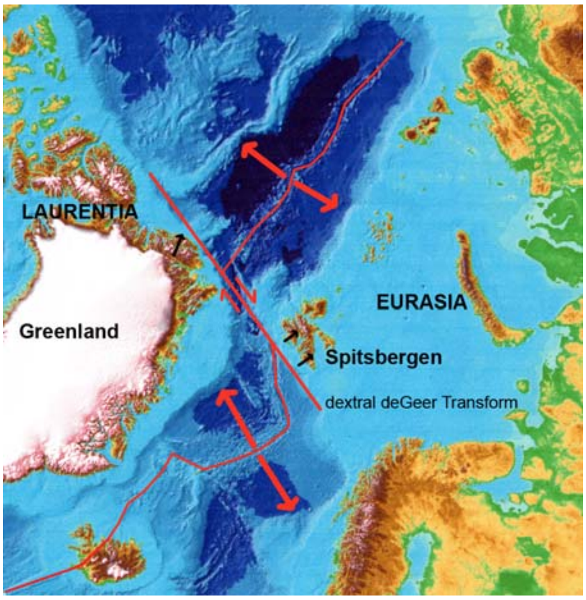

Figure 2. The dextral de Geer transform in the Arctic separating Spitsbergen from North Greenland. Black arrows in both corresponding areas show that tectonic transport in the Tertiary foldbelt cannot be related directly to transform movements.

Fig. 3. Thrust sheets of the Spitsbergen Tertiary Foldbelt north of Kongsfjord. Tectonic transport to

The spreading system in the North Atlantic changed its configuration in early Tertiary time (chron 24) and moved from the west to the east of Greenland (Talwani & Eldholm, 1977). At the same time or possibly one chron earlier, the Eurasian basin of the Arctic Ocean started to open (Srivastava, 1985). During the initial phases of spreading, the two oceanic systems were connected by a dextral continental transfrom fault which separated the Laurentian plate from Eurasia (Fig. 2). In a rather late stage, the zone of weakness produced by the transform fault, became the site of a connecting spreading axis (Kristoffersen, 1990). Effects of the transform system should be preserved in Spitsbergen and North Greenland. In both areas there are, however, compressive foldbelts of a roughly comparable age. This led Harland (1969) to suggest that the de Geer fault could have produced a transpressive foldbelt.

As a consequence, the West Spitsbergen foldbelt became the focus of structural investigations in the following decades (Birkenmajer, 1972; Lowell, 1972; Craddock et al., 1985). The results of these analyses can be summarized as follows:

There is a belt of clear thrust tectonics between Kongsfjord and Sørkapp directed to the E and NE (Fig. 3). The maximum compression appears to be located in the north, where a series of nappes on the Brøgger Peninsula involve metamorphic units of the Caledonian basement. Tertiary strata are marginally affected. The stratigraphy of these strata, mainly terrestrial sediments, is so poor, however, that no precise date for the time of deformation can be given. The foldbelt is not an orogen in the classical sense as a product of an active continental margin as there is no evidence for subduction, synorogenic magmatism, metamorphism or a thickened crust (CASE Team, 2001). Dextral strike-slip faults are hard to find in the foldbelt, the deformation consists mainly of orthogonal foreland thrusting (Maher et al., 1986). A responsible strike-slip fault might, however, be located offshore. This possibility was suggested by Craddock and his students after a period of detailed onshore work (Craddock et al., 1985; Maher et al., 1986).

The solution of the structural problem is found in the corresponding margin of North Greenland. Whereas a transform fault should produce structures directed away from the fault on either side (i.e. SE-wards in Greenland), the direction of tectonic transport in North Greenland is the same as in Spitsbergen, i.e. to the E and NE. The foldbelt therefore has nothing to do with the de Geer Transform Fault. Tessensohn and Piepjohn (2000) have suggested a formation of the North-Greenland and Spitsbergen thrust belts by northward movement of the separate Greenland plate before the transform separation of the two areas.

Discussion

If one returns to the Antarctic with the Arctic scenario in mind, it is clear that the system here is more complicated in its oceanic development. A large number of parallel fracture zones is responsible for a cumulative offset of 2000-3000 km between the Mid-Oceanic Ridges of the Southeast Indian Ocean and the Southeast Pacific (Fig. 1).

A subparallel set of faults traversing NVL (Fig. 4) could provide the evidence for strike-slip movements during the period, when Antarctica and Australia were still linked together in a small land bridge between Tasmania and Victoria Land. The pull-apart basins described in NVL (Roland & Tessensohn, 1984) would fit into a continental transform setting (example Dead Sea transform). If this assumption is true, the age of this fault set in NVL should be in the order of around 35-40 my, the time when the land bridge was finally broken-up. This process allowed the climate-relevant circum-Antarctic current to link the Atlantic, the Indian Ocean and the Pacific, while the Drake passage was still closed as the last connection between Antarctica and the rest of the continental world.

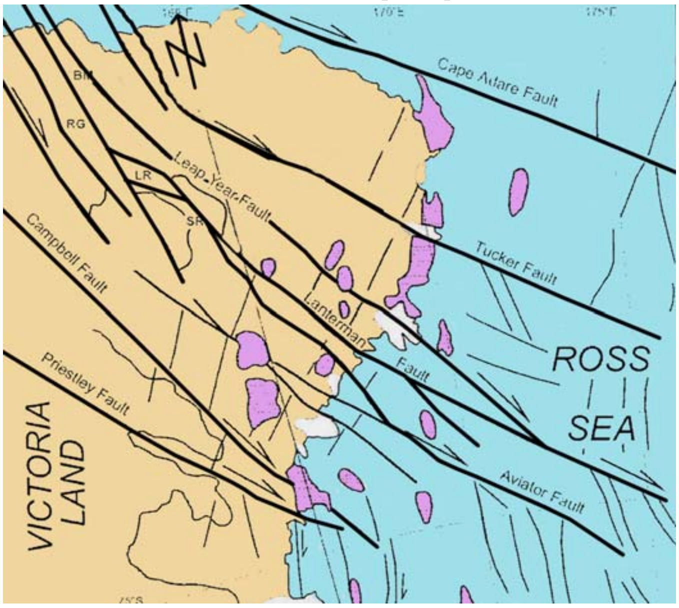

Figure 4. Set of faults in North Victoria Land supposedly related to Balleny transform system (simplified after Salvini et al., 1997).

There is, however, a major problem with both interpretations, even a paradoxon: Whereas the oceanic offset between Tasmania and NVL is sinistral in character (Fig. 1), the strike-slip faults in NVL are clearly dextral (Rosetti et al., 2002). A convincing interpretation of this paradoxon has still to be found.

Consequently this area is one of the targetsof the IPY-project “Plates and Gates” which is aimed to investigate the tectonic evolution of the polar oceans which is so relevant for the development of the global climate from the past to the present.

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