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The field and remote sensing analysis of the Kerguelen Archipelago structure, Indian Ocean

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ABSTRACT

The Kerguelen Archipelago is part of an oceanic plateau with a complex history. Little work has been done on the tectonics of the onshore areas, even though the extensive outcrop renders the islands especially good for structural work. We present the results of three field campaigns and remote sensing analysis carried out in the main Kerguelen Island, around Val Travers valley and Mt Ross volcano (Central Plateau) and in the Rallier du Baty peninsula (SW part of the archipelago). We have mapped faults, fracture sets, and the location and geometry of intrusive bodies. We found that the plateau basalt lavas that make up most of the area are densely fractured, crossed by many veins, dykes and some small faults. This work provides a general framework for the structure of Kerguelen Archipelago that is dominated by 110°-striking faults and veins, dyke swarms and an alignment of recent central volcanoes, which have formed in N-S to NNW-SSE directed extensional stress field. The other structures are fractures, veins and dykes which strike 130–150°, 000° and 030–050°. They are likely related to transform faults of the Indian oceanic crust and to faults of the north Kerguelen Plateau (offshore basement of the archipelago). These buried structures were likely re-activated by a low magnitude stress field.

1. Introduction

The Kerguelen Plateau is sometime described as an old Large Igneous Province (LIP) located on a young oceanic crust (Giret et al., 2003). From the onset of its formation during the lower Cretaceous until now, the Kerguelen hot spot has produced the second largest LIP on Earth (Giret et al., 2003). The rifting of the plateau along the SE Indian mid-oceanic Ridge (SEIR) followed by its break-up has formed NW-SE-striking normal faults in the plateau basalts (Rotstein et al., 2001).

The Kerguelen Archipelago is the largest onshore area of the Kerguelen Plateau (Fig. 1). Its linear structures, such as fractures and faults, and magma injections, such as dykes and intrusive complexes, may be shaped by structures inherited from the rifting phase and by active far-field (mid-oceanic ridge spreading) and near-field (ongoing magma activity) movements. This paper combines remote sensing and field observations to investigate the structure of the archipelago. The remote sensing data provide information about the strike and statistical occurrence of onshore lineaments, such as fractures and dykes. The field campaigns reveal the structures causing the lineaments (e.g. fractures and faults), enable a precise mapping of small-scale intrusions (mostly dykes) and mapping of the geometry of the largest intrusive complex of the archipelago on the SE part of Rallier du Baty peninsula (Fig. 2). These data allow us to define a model that attempts to explain the origin of the abundant fracturing on Kerguelen and provide a tectonic context for the deformation.

2. Geological setting

The Kerguelen plateau is a 2300 km long, NNW-SSE-elongated submarine plateau located on the Indian Ocean crust, south of the SEIR. The plateau is divided into several morphological units (e.g. Fig. 1).

The formation of the Kerguelen Plateau is closely linked to sea-floor spreading between Antarctica, Australia and India that initiated 132–136 Ma ago (Powell et al., 1988; Müller et al., 2000). The South Kerguelen Plateau (SKP), the Elan Bank, the Central Kerguelen Plateau (CKP) and Broken Ridge, the 90°E Ridge and the Skiff Bank, and, eventually, the North Kerguelen Plateau (NKP), formed successively since 120 Ma (Coffin et al., 2002; Duncan, 2002).

At 43 Ma, Australia and Antarctica spread apart on the NW-SE-striking and newly formed SEIR (Rotstein et al., 2001) that was located in the area now occupied by the Kerguelen Plateau. The SEIR is responsible for the separation of Broken Ridge and 90°E Ridge from the rest of the LIP. The

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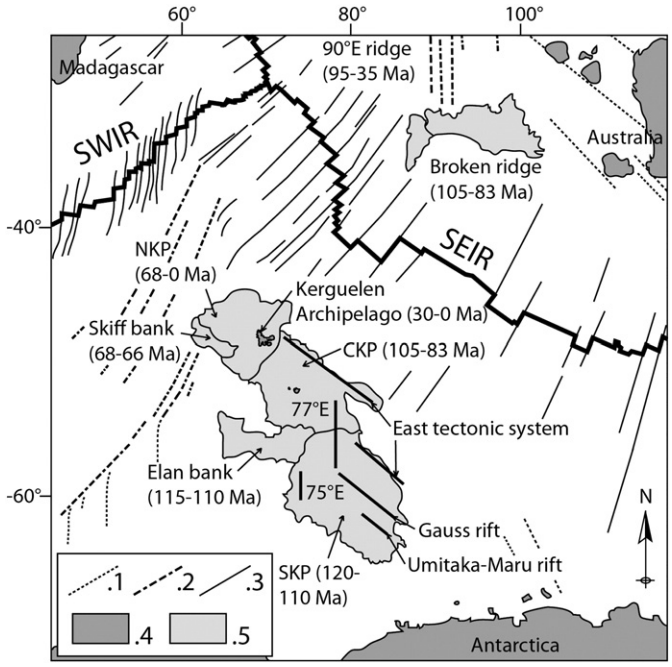

Fig. 1. The Kerguelen Plateau and the Indian Ocean spreading system. The submarine structures are drawn from the gravity map of Rotstein et al. (2001); SEIR: South East Indian Ridge, SWIR: South West Indian Ridge, SKP: South Kerguelen Plateau, CKP: Central Kerguelen Plateau, NKP: North Kerguelen Plateau. 1. Lineaments (probably transform faults) formed from 133 Ma with an initial NE-SW orientation, 2. Lineaments formed from 99–96 Ma with an initial N-S orientation, 3. Transform faults formed from 43 Ma, 4. Onshore lands, 5. Offshore Kerguelen Plateau.

break-up was preceded by rifting phases that formed NW-SE-, N-S- and E–W-trending structures in the plateau basalts. The NW-SE-striking structures are normal to the extension direction and correspond to ridges and normal faults, which sometimes delimit tilted blocks, formed between 88 Ma and 43 Ma (Coffin et al., 1986; Rotstein et al., 1991; Fritsch et al., 1992; Rotstein et al., 1992; Royer and Coffin, 1992; Munschy et al., 1993; Angoulvant-Coulon and Schlich, 1994; Könnecke and Coffin, 1994). Two N-S striking grabens named the 77°E and 75°E grabens are pull-apart related to sinistral strike-slip movements along the NW-SE structures (Munschy et al., 1993). The E–W direction corresponds to a rift zone in the Banzare bank (SKP, e.g. Fig. 1) and its origin is unknown (Charvis et al., 1993; Angoulvant-Coulon and Schlich, 1994).

From 43 Ma, the hot spot activity was increasingly confined in the Antarctic oceanic plate and the NKP (68–0 Ma) continued to form. By 25 Ma, Kerguelen magmatism was fully in an intra-plate position (Giret, 1990). The Kerguelen Archipelago formation initiated at this moment (from 30 Ma; Nicolaysen et al., 2000; Coffin et al., 2002). This 6500 km^2 set of islands is mainly made of plateau basalts (e.g. transitional-tholeiitic to alkaline basalts) that forms 1–5 m thick lava flows dipping 2–3° toward the SE (Nougier, 1970a). Several differentiated magma complexes are intruded in the plateau basalts. The largest magma intrusions are located in the Société de Géographie peninsula, in the western De l'Ouest Island and in Rallier du Baty peninsula (Fig. 2). There are also several recent central volcanoes located along an E–W line in the southern part of the main Kerguelen Island. The Mt Ross (1852 m) volcano for example, is 2–0.1 Ma old (Weis et al., 1998). Also, the active volcanoes of the western part of Rallier du Baty peninsula have erupted recent trachyte lava flows and pumice deposits, which cover the eroded intrusive complexes (Gagnevin et al., 2003).

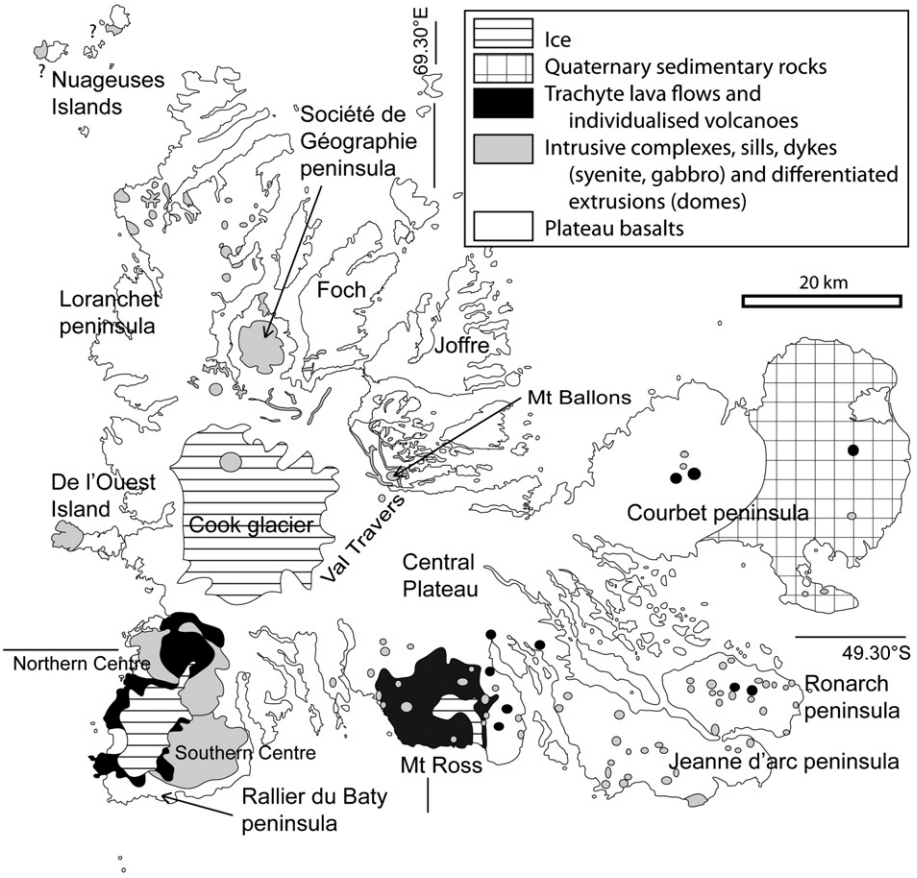

Fig. 2. Kerguelen Archipelago and topographic features referred to in the text (after Lameyre et al., 1984; Gagnevin et al., 2003).