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Pluton-dyke relationships in a Variscan granitic complex from AMS and gravity modelling. Inception of the extensional tectonics in the South Armorican Domain (France)

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ABSTRACT

The Carnac granitic Complex (South Armorican Domain, Western France) was emplaced during Late Carboniferous times in the deepest Variscan unit, roofed by two major extensional shear zones. Through the acquisition and interpretation of field data, Anisotropy of Magnetic Susceptibility and gravity data, emphasized by petrological and structural observations, we address the emplacement model and possible magmatic processes involved between dyking to massive plutonism in a synkinematic context. Gravity modelling highlights an overall eastward thinning of the pluton, and several deep zones in the western part of the complex, interpreted as the pluton feeder zones. The internal granitic fabric, developed in a sub-solidus state, shows marked planar-linear anisotropy, consistent with a vertical shortening in the WNW-ESE regional stretching regime and eastward magma spreading. This study documents the occurrence of numerous NNE-SSW trending dykes within the eastern part of the pluton, suggesting that this granitic Complex formed by the coalescence of dykes oriented perpendicular to the regional stretching direction, and thus interpreted as large-scale "tension gashes". The synkinematic character of the Carnac Complex intrusion, recently dated at ca. 319 ± 6 Ma, thus times the inception of the late-orogenic extensional deformation experienced in the whole South Armorican Domain.

1. Introduction

In many collisional orogens, the thickened crust experiences extensional tectonics during late-orogenic stages, coeval with a widespread crustal melting, responsible for the emplacement of a large volume of granitic magma in the middle to upper crust (e.g. Le Fort, 1981; Harris and Massey, 1994; Faure, 1995; Whitney et al., 2004; Brown, 2005; Faure et al., 2008). The tectonic framework of the late-orogenic evolution is then dominated by extensional tectonics leading to the formation of large-scale extensional shear zones that accommodate the stretching of the continental crust (e.g. Wernicke, 1981; Lister et al., 1984; Malavieille, 1993).

Internal fabrics of granitoids are often regarded as representative strain markers to investigate crustal deformation (e.g. Cloos, 1925; Brun and Pons, 1981; Gapais and Barbarin, 1986; Paterson et al., 1989; Faure and Pons, 1991; Faure, 1995; Talbot et al., 2005a,b). Dyke swarms that may surround the granitic plutons can be used to provide a minimum estimate of crustal extension (Passchier, 1990). During the last decades, the structural and genetic relationships between plutons and their associated dyke swarm have been widely investigated (Clemens and Mawer, 1992; Petford et al., 1993, 2000; Rubin, 1995; Petford, 1996; Talbot et al., 2005b; Bartley et al., 2006). It was argued that the dykes are either fed by magma coming from the pluton (e.g. Baker, 1998; Clemens and Mawer, 1992; Rubin, 1995) or play a significant role in building the pluton (e.g. Petford et al., 2000).

This study focuses on the Variscan Carnac Complex, made of a granitic pluton and its surrounding dyke array that was emplaced in the South Armorican Domain during the late tectonic evolution of the Variscan belt (Turrillot et al., 2009). Using the Anisotropy of Magnetic Susceptibility (AMS), the mineral preferred orientation of the Variscan Carnac granitic pluton and of its surrounding dykes has been determined. Based on geological mapping, recent studies suggested that the Carnac Complex emplacement may record initial stages of the late-orogenic extensional tectonics (Augier et al., in press). The AMS survey enabled us to better understand the late-stage internal structure

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and fabric orientations developed within the crystallizing magma chamber, which will, in turn, be used to i) determine the principal strain axes that develop during the emplacement of the Carnac Complex and ii) characterize the relationships between the pluton and its dyke swarm. However, the magnetic fabric provides structural information restricted to the exposed level of the complex, but does not inform on the deep structures such as the geometry of the feeder zones or the pluton thickness variations. Therefore, a combined AMS and gravity study of the Carnac Complex is achieved; it will provide new insights on the pluton shape at depth, and will improve the understanding of the complex overall architecture in the context of a synkinematic emplacement. Combined with microstructural observations, the role of magma dynamics-related deformation and/or regional stretching on the fabric development both in the pluton and in the dyke swarm can be discussed. These new data enable us to propose an emplacement model, which is also discussed in terms of regional implications in the light of the extensional tectonic framework that has been previously proposed for this area of the South Armorican Domain (Gapais et al., 1993; Turrillot et al., 2009).

2. Geological setting

2.1. General framework

The orogenic evolution of the European Variscides includes Ordovician rifting, Silurian subduction, Silurian–Devonian multiple collisions, Late Devonian-Carboniferous intra-continental deformation, and Upper Carboniferous late-orogenic extension (Dewey and Burke, 1973; Matte, 1986, 1991, 2001; Gapais et al., 1993; Faure, 1995; Cagnard et al., 2004; Faure et al., 2005). The French Massif Armoricain is classically subdivided into several tectono-metamorphic domains by two major dextral strike-slip shear zones active during the Upper Carboniferous times, namely, the North Armorican Shear Zone (NASZ), and the South Armorican Shear Zone (SASZ) that splits into a WNW-ESE northern branch and a NW-SE southern branch (Fig. 1a; Cogné, 1974; Watts and Williams, 1979; Jégouzo, 1980). However, these Carboniferous shear zones do not represent suture zones or plate boundaries. Concerning the Early Variscan collisional events, the Nort-sur-Erdre fault is considered as the suture zone between Central Armorican and South Armorican Domain (Fig. 1a) (Faure et al., 2005, 2008; Ballèvre et al., 2009).

The South Armorican Domain is limited to the north by the southern branch of the SASZ (Fig. 1a; Berthé et al., 1979; Jégouzo, 1980). There, several tectono-metamorphic units are recognized from top to bottom (Fig. 1b; e.g. Cogné, 1974; Le Corre et al., 1991; Ballèvre et al., 1994): (1) Upper units characterized by well preserved HP–LT metamorphic rocks in the Bois de Céné, and Ile de Groix blueschist klippes (Bosse et al., 2002), and in Vendée and Belle-Ile-en-Mer porphyroids (Le Hébel et al., 2002); (2) Intermediate units or "Schistes de la Vilaine" group equilibrated upon a MP-MT Barrovian geothermal gradient (Triboulet and Audren, 1988; Goujou, 1992; Brown and Dallmeyer, 1996); and (3) Lower unit of HT-MP rocks consisting of migmatites (i.e. metatexites) and migmatitic granites (i.e. diatexites) intruded by large volumes of late to post- migmatitic granites (e.g. Audren and Le Métour, 1976; Marchildon and Brown, 2003).

Unlike Central Armorica, the South Armorican Domain underwent extensional tectonics during the last stage of the Variscan orogenic evolution (e.g. Gapais et al., 1993; Cagnard et al., 2004; Turrillot et al., 2009). The overall tectonic framework of the South Armorican Domain consists of Lower Unit migmatites and granites, exposed in tectonic windows overlain by the Intermediate Unit. At the regional scale, a widespread extension is well documented in the Sables d'Olonne area where it is accommodated by a pervasive thinning of the entire metamorphic sequence (Cagnard et al., 2004), whereas in the Morbihan area, Lower Unit high-grade rocks are roofed by localized top-to-the-WNW, and top-to-the-ESE extensional shear zones, namely, the Quiberon Shear Zone (QSZ), and the Sarzeau Shear Zone (SSZ), respectively (Gapais et al., 1993; Turrillot et al., 2009).

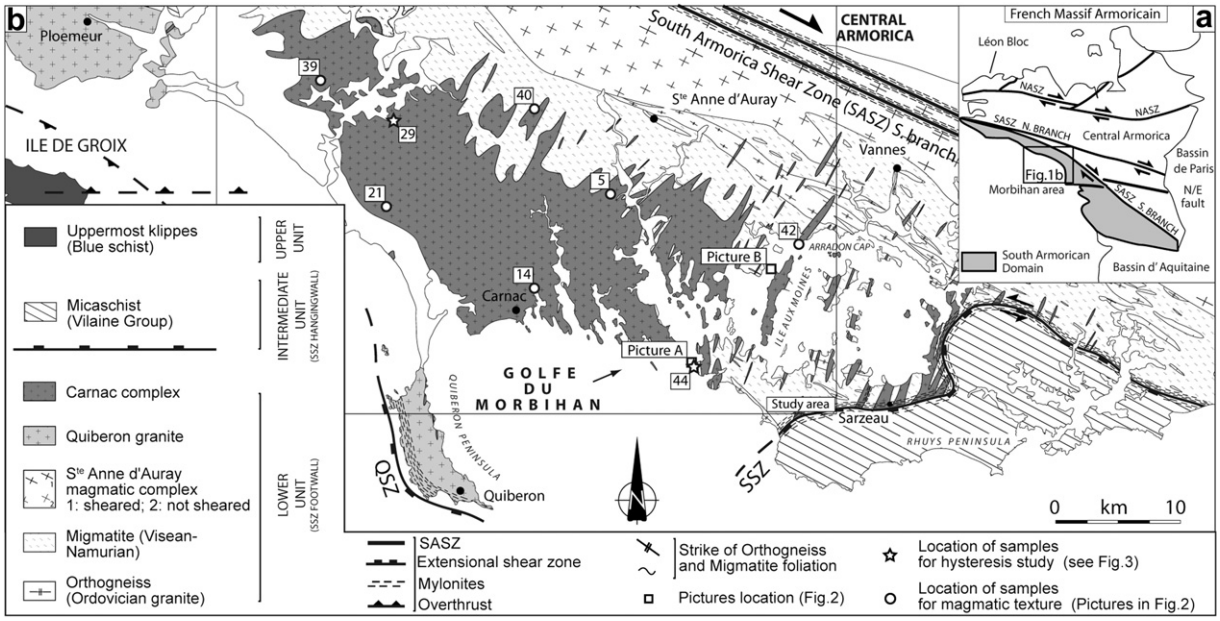

Fig. 1. (a) Simplified map of the Massif Armoricain. NASZ: North Armorican Shear Zone, SASZ: South Armorican Shear Zone, N. Branch: Northern Branch, S. Branch: Southern Branch; (b) Structural map of the Morbihan area in the South Armorican domain (Modified from Turrillot et al., 2009). The main tectonostratigraphic units and their internal features are depicted. The Intermediate and the Lower units are separated by the extensional Sarzeau Shear Zone (SSZ) in the Rhuys Peninsula, and the Quiberon Shear Zone (QSZ) in the Quiberon Peninsula.