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Structural inheritance and coastal geomorphology in SW Brittany, France: An onshore/offshore integrated approach

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ABSTRACT

The Variscan crystalline basement exposed along the SW Brittany coast recorded extensive long-term planation processes during Mesozoic times. Detailed onshore-offshore mapping (600 km^2) in the Penmarc'h-Concarneau granitic coastal area reveals a km-scale, deeply fractured submarine rocky shelf. High-resolution offshore imagery (bathymetry and seismic reflection dataset), combined to structural field investigations, on these surfaces allow us to identify a preserved network of both ductile and brittle structures. The inherited fault pattern is dominated by the N160°E-trending and long-lived Concarneau-Toulven fault zone (CTFS) that separates two distinct morphostructural blocks, and strongly influences the seaward limit of the Concarneau submarine rocky shelf, as well as the linear coastline of the Concarneau embayment. The structural imprint of the CTFS decreases progressively westwards with respect to a composite network of large-scale N50°E- and N140°E-oriented faults bounding the seaward edge of the Penmarc'h rocky shelf. The latter in turn splits into three large-scale blocks along N50°E- (La Torche Fault – LTF), N140°E- (Saint Guénolé Fault – SGF) and N160°E-trending normal faults. The morphostructural evolutionary model applied here to the Penmarc'h-Concarneau granitic coastal area resulted from the combined effects of structural Variscan inheritance and post-Variscan tectonics. Paleo-stress analysis of striated fault planes indicates three main Cenozoic tectonic events, inferred to have operated from Eocene to post-Oligocene times. The 3D-architecture of the Concarneau embayment, as a rocky shelf partially sealed with quaternary sediments, chiefly resulted from the reactivation of the CTFS during Eocene and Oligocene times. Further west, the surface of the Penmarc'h rocky shelf was tilted southeastward by the brittle reactivation of the LTF, and dissected by a horst-graben network post-Oligocene in age. The present-day morphology of the Penmarc'h and Concarneau domains depends on distinct driving processes: the Concarneau N160°E coastline is clearly controlled by tectonic processes *via* the CTFS, while the Penmarc'h headland land-sea contact appears to have been shaped by post-Cenozoic eustatism.

1. Introduction

The extensive planation event experienced by the Brittany coastal area in Mesozoic times resulted in the flattening of previous Variscan relief (de Martonne, 1906; Guilcher, 1948). In the South Armorican Domain (SAD) under study, the main planation surface, pre-Cenomanian in age, was accompanied by the uplift of the Armorican massif, in relation with the opening of the Bay of Biscay (Guillocheau et al., 2003; Bessin, 2014) (Fig. 1).

During Cretaceous and Cenozoic emersion episodes, Armorican granitic rocks recorded additional weathering (Estéoule-Choux, 1983; Wyns, 1991), thus contributing to ongoing alteration of the initial planation surface in response to large-scale lithospheric buckling (Wyns, 1991; Guillocheau et al., 2003; Bessin et al., 2015). In general, the flat-lying coastal surfaces in Brittany likely formed as deeply weathered coastal plains that experienced both climatic and tectonic processes during post-Variscan times (Wyns, 1991).

The SW Brittany coast is known to be a long-lived and polyphased morphostructural feature (Duperret et al., 2016), and its temporal development is addressed in the present work, not only for present-day times but also with respect to the tectonic processes that operated during Cenozoic times, hence leading us to discuss the role of structural inheritance in the 3D architecture of the current SW Brittany coast. Firstly, its morphostructural arrangement and spatio-temporal evolution are discussed about a 40 × 15 km onshore-offshore area extending from the inland domain (the Penmarc'h-Concarneau coast) to the seaward rocky inner shelf. Our onshore-offshore morphostructural approach is chiefly based on

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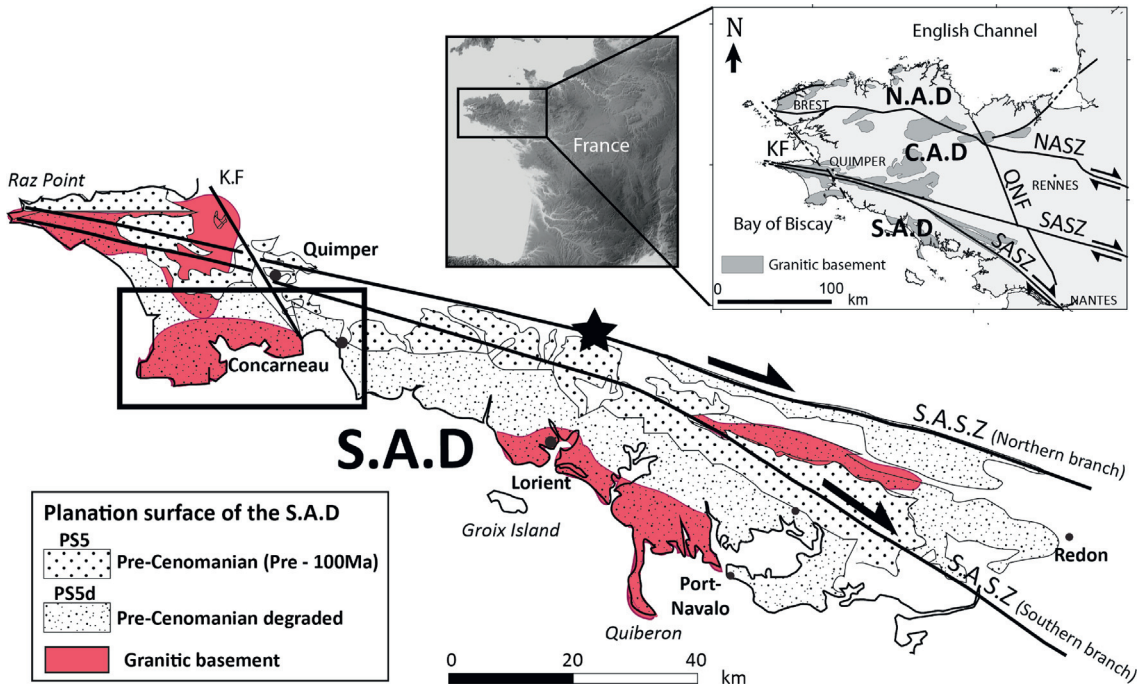

Fig. 1. Synthetic geomorphological map of planation surfaces (and their ages) in the South Armorican Domain (modified from Bessin et al., 2015). Rectangle shows the study area. The black star represents the Lorient earthquake location (2002, Mw 4.27). N.A.D, C.A.D and S.A.D correspond to the North, Central and South Armorican domains. S.A.S.Z. and N.A.S.Z., South and North Armorican Shear Zone; KF and QNF: Kerforne and Quessoy-Nort-sur-Erdre Faults.

complementary high-resolution dataset comprising newly-acquired LiDAR, echosounder and seismic reflection records. The ancient deformed terrains extend laterally offshore into marine areas devoid of any sedimentary cover, hence providing a powerful method for imaging submerged basement structures, as successfully applied elsewhere in Brittany (Le Gall et al., 2014). Morphological analyses, further combined to seismic profile interpretation and structural observations, highlight the role of both ductile and brittle inherited structures in the evolving morphology of the Penmarc'h-Concarneau rocky platform (PCP). Emphasis is put on brittle structures, the repeated reactivation of which since Variscan times leading to the present-day coast-platform morphological pattern. The structural interpretation of lineaments extracted from remote sensing imagery has been calibrated by extensive observations and field measurements. This also provides relative timing constraints about the successive brittle stress regimes recorded by the rocky basement since Variscan times.

2. Geological and morphological settings

The 40 km-long coastal area under study encompasses the Penmarc'h peninsula to the west, and the Concarneau embayment to the east (Fig. 2).

Regional geology is dominated by an elongated EW-trending granitic belt, involving the very little deformed Pont-L'Abbé and Trégunc Carboniferous granites (305 and 315 Ma in age, respectively) (Fig. 1). Variscan ductile strain is restricted to the northern edge of the Pont-L'Abbé granite where intense sinistral ductile shearing is observed in a narrow N70°E-oriented belt that extends further north in its low-grade metamorphic host-rocks (gneiss and micaschists) (Béchennec et al., 1997). These granitic and metamorphic Variscan terranes form, in addition to the Audierne ophiolitic complex further north, the western part of the SAD, south of the N110°E-trending South Armorican dextral shear zone (SASZ) and its 305–315 Ma-old syntectonic granites (Berthé et al., 1979; Gapais and Le Corre, 1980; Tartese et al., 2011) (Fig. 2). These metamorphic and granitic terranes are stepped by six planation surfaces. One major planation surface, pre-Cenomanian in age and known as the Armorican Planation Surface, is mainly observed in the SAD (Fig. 1). This landform was later buried by Late Cretaceous sediments, in turn exposed at the surface by denudation processes in the Early Eocene (Bessin et al., 2015).

These events mostly occurred in the SAD during successive rejuvenation of N110°E- (SASZ) and N160°E-trending (Kerforne, KF) Variscan faults (Fig. 1). The more widely distributed Kerforne fault/fracture network probably initiated as late Variscan right-lateral faults, in response to the N-S-trending compression that prevailed during late Carboniferous times in Armorica (Rolet et al., 1986). In Stephanian times (307–298 Ma), part of the SASZ pattern was rejuvenated as dextral wrench faults that controlled the emplacement of narrow pull-apart sedimentary basins along the Quimper-Raz Point axis (Garreau, 1975; Barrière et al., 1985; Béchennec et al., 1997) (Fig. 1). The Kerforne-type structures were then repeatedly reactivated in various ways during post-Variscan times. As early as Jurassic times, they were intruded further north by a ca. 200 Ma-old doleritic dyke swarm (Caroff et al., 1995; Jourdan et al., 2003) related to the North Atlantic ocean opening (McHone et al., 1987; Ziegler, 1987; Piqué and Laville, 1996; Caroff and Cotten, 2004). The southern margin of the Armorican massif was initiated during the Early Cretaceous, consequently to the rotation of the Iberian Peninsula and the contemporaneous opening of the Bay of Biscay (Thinon, 1999; Paquet et al., 2010).

Later on, from the Late Cretaceous to Oligocene, the Pyrenean collision produced N- to NW-trending compression in its foreland, as evidenced in the Bay of Biscay (Thinon et al., 2001). Further north, in SW Brittany, one major mid-Eocene sedimentary depocenter is documented in the Concarneau onshore area, as the 10 × 5 km