



Tectonic and geomorphic analysis of the Belledonne border fault and its extensions, Western Alps



Jérémy Billant ^{*}, Jean-Claude Hippolyte, Olivier Bellier

Aix-Marseille Université, CNRS, IRD, CEREGE UM34, 13545 Aix-en-Provence, France

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ABSTRACT

In the western Alps, the NE trending Belledonne fault system extends from the Mont Blanc massifs in the NE to the Vercors massif in the SW. It includes the Belledonne border fault, defined by an alignment of micro earthquakes ($M_L \leq 3.5$). Focal mechanisms and their respective depths indicate a crustal scale NE trending dextral strike-slip faulting.

This study aims at better constraining the geometry, the fault kinematics and slip rate of the faults of the Belledonne fault system by using a multidisciplinary approach that includes tectonics, geomorphology and geophysics.

New clues of potential Quaternary deformations are observed: 1 — the right-lateral offsets of morphologic markers (talwegs) along the NE trending Arcalod fault at the north-eastern termination of the Belledonne border fault; 2 — the left-lateral offset of the valley carved by the Isère glacier along the NW trending Brion fault, which is consistent with the fault kinematics deduced from the focal mechanisms.

Stream network anomalies along the Belledonne border fault are related to glacial erosion processes rather than faulting. However, fault kinematics analysis along the Belledonne border fault allows us to determine a strike-slip tectonic regime characterized by horizontal ENE trending σ_1 stress axis. It is consistent with the mean trend of the P and T axes deduced from the focal mechanisms. We display evidences that this stress state is Messinian to Quaternary in age and occurred after an Oligocene to Messinian strike-slip tectonic regime characterized by horizontal WNW trending σ_1 .

Fault slip rates cannot be assessed because of the lack of morphologic features with constrained ages. However, it is likely that the presented geomorphic markers are older than Würm.

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1. Introduction

Although continental interiors are generally characterized by low strain rates, they can be struck by destructive earthquakes (e.g., the 1356 Basel Earthquake, Switzerland (Fäh et al., 2009), the 1811–1812 New Madrid earthquakes, United States (Tuttle et al., 2002), the 1909 Lambesc earthquake, France (Baroux et al., 2003; Chardon et al., 2005; Lacassin et al., 2001), and the 2001 Gujarat earthquake, India (Rastogi, 2004)). A direct consequence of these low strain rates is that the recurrence intervals between destructive earthquakes can reach up to several millennia and thus historical seismicity cannot document an entire earthquake cycle. Moreover, climatic conditions may not favor surface preservation of active fault traces. Generally, classic approaches developed for highly seismic regions, i.e. historical seismicity investigations and paleoseismology, are strongly limited and may not be suitable to assess seismic hazard in low strain rate areas.

This study takes place in an area as described above and is focused on the central part of a NE trending fault system that we name the Belledonne fault system. It is an alignment of NE-SW striking faults extending from the Aiguilles Rouges and Mont Blanc massifs, in the north-east (alpine external crystalline massifs), to the Vercors massif, in the south-west.

Based on microseismicity, Thouvenot et al. (2003) proposed that a dextral strike-slip fault, the Belledonne border fault, is an active fault bordering the Belledonne massif to the west. Indeed, a NE trending alignment of low magnitude seismic events with a mean focal depth of about 7 km testifies that an active fault affects the crystalline basement (Thouvenot et al., 2003). Until now, no geologic or morphotectonic study allowed mapping this fault on the surface. The aim of this study is to constrain the geometry, kinematics and fault slip rate of the Belledonne fault system, including the active strike-slip fault segment identified at depth by Thouvenot et al. (2003). For this purpose, because of the moderate crustal deformation and high erosion rates prevailing in the study area, a multidisciplinary approach (morphotectonics, faults kinematics, structural analysis and geophysics) is needed in order to constrain fault geometry and kinematics and find

^{*} Corresponding author. Tel.: +33 4 42 97 16 79.
E-mail address: billant@cerge.fr (J. Billant).

offsets of inherited morphologies (e.g., Baize et al., 2011; Cushing et al., 2008; Le Roux et al., 2008; Molliex et al., 2011; Schlupp, 2001).

2. Structural framework

The study area is located at the junction of two alpine domains: the external crystalline massifs and the subalpine massifs. They respectively represent the pre-Triassic crystalline basement and its Mesozoic cover. From north to south, the external crystalline massifs are the Aiguilles Rouges, Mont Blanc, Belledonne and Pelvoux Massifs and the subalpine massifs are the Bornes, Aravis, Bauges, Chartreuse and Vercors Massifs (Fig. 1A). Bauges and Chartreuse massifs are separated from the Belledonne massif by the large Grésivaudan valley where the Isère river flows.

The main faults of the area are NE trending faults cutting the external crystalline massifs (e.g. synclinal median fault, Fig. 1A) (Bodelle and Goguel, 1980). They formed during the Variscan tectonic event as dextral strike-slip faults (Guillot and Ménot, 2009). Injection of magma from lithospheric mantle within some of these fault zones confirms that they cut the entire crust (Guillot and Ménot, 2009). This crustal weakness zone was reactivated during the following tectonic phases, first by normal faulting during the Tethysian extension (Guillot and Menot, 1999; Lemoine et al., 1981) and later by right-lateral strike-slip or reverse faulting during alpine collision (Debelmas and Kerckhove, 1980; Lemoine et al., 1981).

Tethysian extension, that occurred from late Triassic (Barfély and Gidon, 1990) to Dogger, created half-grabens and tilted blocks, mainly along east dipping crustal normal faults (Barfély et al., 1979; Lemoine et al., 1981, 1986).

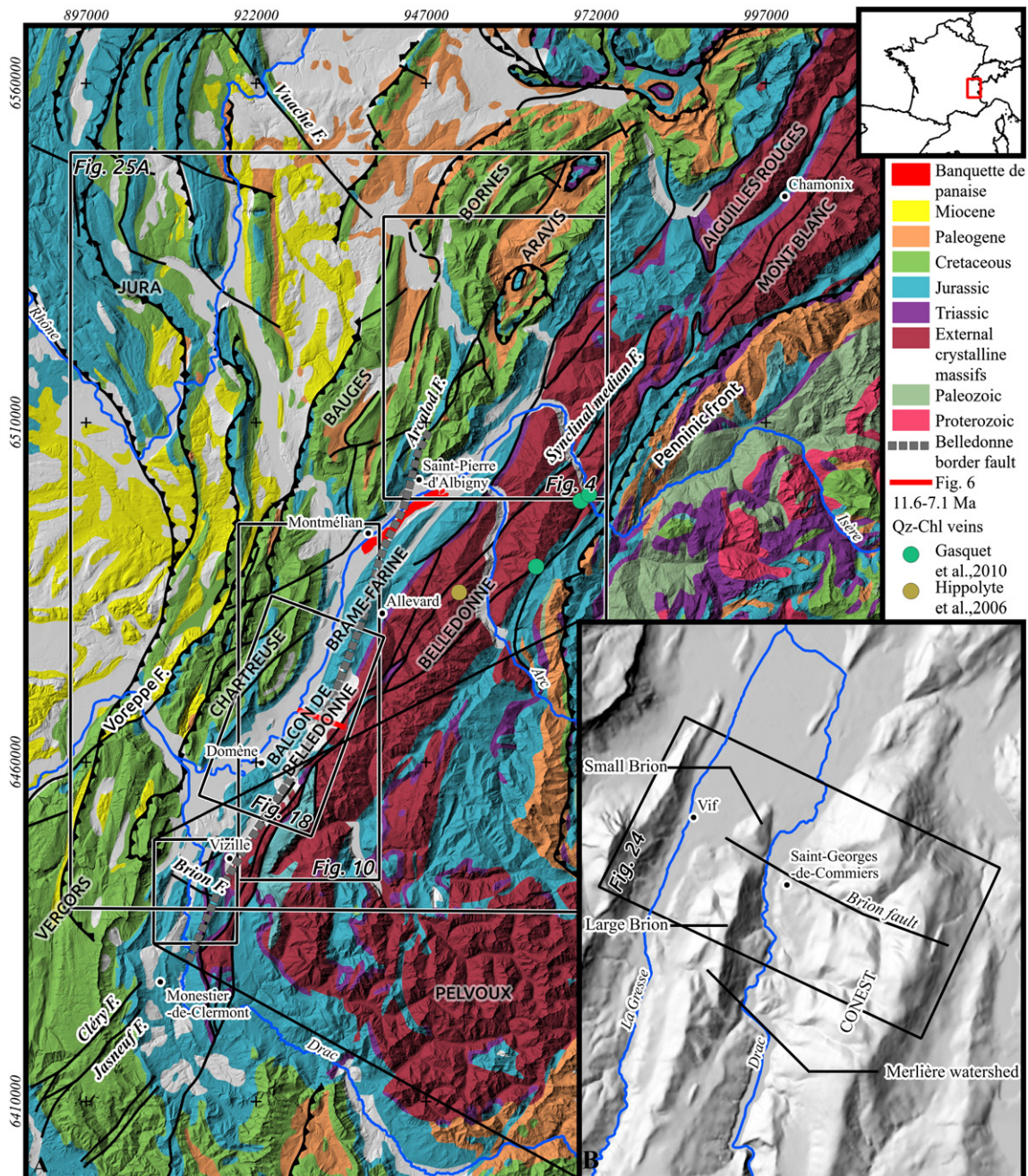


Fig. 1. A: Simplified geological map of the studied area (modified from Bodelle and Goguel, 1980). B: Shaded DEM of the Brion fault area.

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