



Photograph of the month: Boudin centennial



Metasandstone–metapelite multilayer sequence with regularly spaced, layer-perpendicular quartz veins and buckled interfaces, Carrière Mardasson, Bastogne, Belgium. Width of view about 50 m (50°00'55.01"N, 5°44'27.63"E). Photograph Manuel Sintubin, Leuven, Belgium. ©Manuel Sintubin.

This photograph is taken in the Mardasson quarry near Bastogne, Belgium, the locality where 100 years ago the terms *boudin* and *boudinage* were coined. In this outcrop, cusped-lobate buckling of the interface between metasandstone and metapelite is controlled by the presence of pre-existing layer-perpendicular quartz veins. The buckling does not occur where quartz veins are not present. The quartz veins are confined to the fine-grained micaceous sandstone layers and there is a relationship between vein spacing and layer thickness. The veins result from a hydraulic-fracturing event (Kenis et al., 2002, 2005a). Once formed, the quartz veins acted as rigid plates, stronger than the micaceous sandstones. Subsequent layer-parallel shortening caused cusped-lobate buckling of both upper and lower interface in between the quartz veins, i.e. the development of mullions. Deformation was by solution-precipitation processes at 350–400 °C. The characteristic shape of these mullions allows estimation by geomechanical modelling of the rheological parameters of the rock (Kenis et al., 2004, 2005b).

The following section explains the history of geological research in the quarries near Bastogne and the origin of the terms “*boudin*” and “*boudinage*”.

On August 31st, 1908 – 100 years ago – a field trip was organised by the Société Géologique de Belgique to the quarries near Bastogne. During the trip, Max Lohest suggested to use the term “*boudin*” (French for sausage) to describe the structures in this quarry and “*boudinage*” to describe the process causing them because of a similarity to “sausages lying side-by-side”:

“Lorsque l'on voit ces segments renflés sur une surface de stratification étendue, mise à nu par l'exploitation, on croirait voir une série d'énormes cylindres ou boudins alignés côté à côté... sur l'initiative de M. Lohest on a fréquemment utilisé, pour la facilité du langage, les néologismes de *boudiner* et de *boudinage*.” (Lohest et al., 1908).

At this early stage, these terms were used in a purely descriptive way without any kinematic implications. During the field trip,

a discussion unfolded on relative timing of the different deformation features: Xavier Stainier defended his theory of a polyphase brittle-ductile deformation sequence (Stainier, 1907) – first fracturing and veining, then layer-parallel shortening, all prior to the main folding and cleavage development, while Lohest insisted that veining postdated the buckling of the interfaces, folding and cleavage development (Lohest, 1909; Lohest et al., 1908). This set the scene for a century of discussion on the origin of structures in this quarry and of similar “boudins” elsewhere.

In the first half of the 20th century several models were proposed for development of “boudins” at Bastogne (Corin, 1932; Holmquist, 1931; Quirke, 1923; Wegmann, 1932): “*There seems to be nothing in the arts or in nature which can be compared in mechanical origin to boudinages, which makes them the more interesting and the more worthy of study*” (Quirke, 1923). Although most authors thought that the “boudins” at Bastogne were related to “pinch-and-swell” structures described by e.g. Ramsay (1866) and Harker (1889), it was generally agreed that they did not fully resemble these, primarily because of the very different aspect ratio of the segments (Holmquist, 1931; Walls, 1937). Cloos (1947), however, did not make this clear distinction anymore and the term “boudinage”, applied to both types of structures, obtained its current kinematic definition referring to a process of disruption of layers, bodies or foliation planes within a rock mass in response to bulk extension along the enveloping surface (cf. Goscombe et al., 2004). With the name “boudin” taken to mean extensional structures, very similar structures to the ones in Bastogne, 100 km to the north in the North Eifel, were described as “mullions” (Pilgers and Schmidt, 1957). In an attempt to relate the “mullions” of the North Eifel, interpreted as layer-parallel shortening structures (i.e. cusped-lobate folding), and the “boudins” of Bastogne – at that time considered as extension structures – terms such as “L-boudins” or “auslängungs-boudins” and “K-boudins” or “verkürzungs-boudins” were introduced (Brühl, 1969). The “mullions” of Pilgers and Schmidt (1957) became “half-boudins” (Brühl, 1969). It was quickly realised that this new terminology was only contributing to the confusion, taking into account that the association of the term “boudinage” with bulk extension was already too entrenched in English literature (Mukhopadhyay, 1972). Mukhopadhyay (1972) and Spaeth (1986), and more recently Urai et al. (2001), considered the structures in the entire Ardenne-Eifel region as mullions. Independently, the idea of “shortened boudins” became popular, primarily based on the atypical aspect ratio of the segments (Jongmans and Cosgrove, 1993; Lambert and Bellière, 1976; Rondeel and Voermans, 1975; Vanbrabant and Dejonghe, 2006).

A century of debate primarily focused on the cusped-lobate and sausage-like geometry of the sandstone-pelite bedding interface, but the quartz veins were mostly ignored. An investigation of the kinematic significance of the veins in the overall structure (Kenis et al., 2005a, 2002) and numerical modelling (Kenis et al., 2004) led to the mullion model presented above (Kenis et al., 2005b). Thus, the hypothesis initially postulated by Xavier Stainier in 1907 is again remarkably up to date!

Despite the conclusion that the kinematics that caused the exceptional structures in the Ardenne-Eifel region have nothing to do with the process of boudinage as we use the term today, we should not forget that the quarries near Bastogne are the original site where the terms “boudin” and “boudinage” were first used in a geological context. These terms would not have existed if that particular field trip by French-speaking geologists had not taken place in 1908. Because of their exceptional and historically significant

structures, the sites near Bastogne deserve to become a natural heritage site (Kenis and Sintubin, 2007).

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Manuel Sintubin

Katholieke Universiteit Leuven, Department of Earth & Environmental Sciences, Celestijnenlaan 200E, 3001 Leuven, Belgium
E-mail address: manuel.sintubin@ees.kuleuven.be

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