



# Formation of Taconic mélanges and broken formations in the Hamburg Klippe, Central Appalachian Orogenic Belt, Eastern Pennsylvania<sup>☆</sup>

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## ABSTRACT

The Hamburg Klippe of the Central Appalachian orogenic belt exposed in eastern Pennsylvania displays a complex record of poly-phase mélange and broken formation development in a convergent margin setting. It includes an imbricate stack of tectonic slices, which consist of upper Cambrian to Upper Ordovician deep-water and continental slope sedimentary rocks, emplaced by gravity sliding onto the Laurentian passive margin during deposition of the Octoraro Sea basin in the Early Ordovician. Based on their internal structure and stratigraphy, the block-matrix ratios and relations, and the inferred tectonic settings of origin, we have differentiated the following mélanges and broken formations, whose evolutionary stages coincide with specific deformational phases in a complete orogenic cycle from subduction to collision: (i) sedimentary broken formations without exotic blocks, formed by *in situ* and local down-slope remobilization during the early stages of closure of the Octoraro Sea basin in the Early Ordovician; (ii) two types of sedimentary mélanges with exotic blocks, formed at the front of the advancing accretionary wedge during the Middle Ordovician subduction of the Laurentian continental margin beneath a microcontinent–magmatic arc tectonic assembly; (iii) layer-parallel, extensional broken formation and a diapiric mélange, formed in the outer trench and at the toe of the accretionary wedge, respectively, during the early–Late Ordovician; (iv) precursory olistostromes, formed during the Late Ordovician collisional episodes as the Hamburg Klippe was emplaced in the Martinsburg Formation on the downgoing Laurentian continental margin; and, (v) contractional deformation-related broken formations, formed at the base of main thrust faults overprinting the previously formed mélanges and broken formations. This sequential development of different mélange types in the Central Appalachians was strongly controlled by the degree of consolidation of the layered strata and their rheological differences, the structural level of mélange formation within the accretionary wedge, and the kinematics of deformational processes.

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## 1. Introduction

Chaotic rock bodies may include olistostromes, mass-transport deposits, broken formations, tectonic mélanges and diapiric occurrences, and commonly form as a result of tectonic, sedimentary and diapiric processes and their mutual interplay and superposition. Their internal structure and architecture display strong evidence for those geological processes that operated in certain tectonic setting(s) and along plate boundaries. The structure and stratigraphy preserved in chaotic rock bodies can also allow us to better understand the tectono–stratigraphic evolution of orogens in which they are preserved (e.g., Festa et al., 2010a, 2010b; Ogawa, 1998). This is the case of different orogenic belts and accretionary complexes around the world where mélanges and olistostromes occur, for example in the Alpine–

Himalayan belt (e.g. Federico et al., 2007; Liu and Einsele, 1996; Ring et al., 1990; Trommsdorff, 1990), circum-Mediterranean orogens (e.g., Camerlenghi and Pini, 2009; Dilek et al., 1999, 2007; Elter and Trevisan, 1973; Festa et al., 2010b; Ghikas et al., 2010; Okay, 2000; Pini, 1999; Robertson et al., 2009), Appalachians (e.g., Cousineau and St-Julien, 1992; Ganis and Wise, 2008; Lash, 1987a; Rast and Horton, 1989; Tremblay et al., 1995), circum-Pacific regions (e.g., Cloos, 1982; Cowan, 1985; Hsü, 1968; Ikesawa et al., 2005; Kimura et al., 1996; Kusky and Bradley, 1999; Matsuda and Ogawa, 1993; Wakabayashi, 1992; Wakabayashi et al., 2010; Yamamoto et al., 2009) and many others.

The Taconic Allochthon of the Central Appalachian orogenic belt of eastern Pennsylvania (Fig. 1) includes some of the best examples of unmetamorphosed chaotic rock body occurrences that provide us with critical structural and stratigraphic evidence to examine the mode and nature of depositional and deformational processes throughout the tectonic evolution of this orogenic belt (Ganis and Wise, 2008; Ganis et al., 2001; Lash, 1987a; Lash and Drake, 1984; Root and MacLachlan, 1978). These examples mainly occur in the Hamburg

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