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Neoproterozoic to early Cambrian Franciscan-type mélanges in the Teplá–Barrandian unit, Bohemian Massif: Evidence of modern-style accretionary processes along the Cadomian active margin of Gondwana?

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ABSTRACT

Mélanges have been reported from a variety of modern tectonic settings and are a hallmark of the Franciscan-type subduction–accretion complexes. In the Precambrian, however, well documented examples of mélanges become extremely scarce. This paper describes in detail Neoproterozoic to early Cambrian mélanges recently recognized in the Cadomian basement of the Teplá–Barrandian unit, Bohemian Massif. The mélanges are of sedimentary and tectonic origin and include voluminous successions of graywackes interpreted to represent mass-transport deposits presumably along the upper slope of an accretionary wedge. The clast compositions indicate multiple episodes of mixing of terrigenous arc-derived and deep-water (?pelagic) material. Moreover, abundant bodies of (meta-)basalts, interpreted as dismembered seamounts or pillow volcanoes, were emplaced tectonically into various structural levels of this sedimentary mélange by two different mechanisms. At an upper level, the irregular to elongated bodies of basalts were offscraped, only weakly strained, and incorporated in the sedimentary matrix that exhibits steep cleavage indicating horizontal pure shear shortening and oblate strain. In contrast, at a lower level, disc-shaped and closely spaced basalt bodies are ductilely sheared and reworked into a flat-lying prolate to plane-strain fabric suggesting horizontal ductile flow, presumably along the base of the accretionary wedge during flat-slab oceanic subduction. Our new U–Pb ages also reveal that the mélange formation continued until the early Cambrian (<527 Ma). We conclude that these sedimentary–tectonic mélanges and the inferred mélange-forming processes are identical to those that operate along modern active plate margins and, in general, reveal their potential as excellent markers for establishing modern-style subduction in Precambrian settings.

1. Introduction

Mélanges are mapable bodies with along-strike dimensions varying from tens of meters to hundred of kilometers that consist of compositionally diverse inclusions chaotically mixed in a significantly finer grained siliciclastic or serpentinite matrix (block-in-matrix fabric; e.g., Cowan, 1985; Festa et al., 2010a, 2012; Hsü, 1968; Osozawa et al., 2009; Raymond, 1984; Sengör, 2003; Silver and Beutner, 1980; Wakabayashi, 2011, 2012; Wakabayashi and Medley, 2004). The composition and metamorphic grade of the mixed inclusions may vary considerably as exemplified by mélanges that juxtapose non-metamorphic to very-low-grade rocks against blueschists, eclogites, and even mantle peridotites and serpentinites. In addition, mélanges are specific geologic objects in that they display extensive stratal disruption to entirely chaotic nature and, in the latter case, do not obey common stratigraphic principles such as superposition and lateral continuity (Hsü, 1968).

Although mélanges occur in a variety of tectonic settings, they are typically an important lithotectonic element of accretionary wedges above subduction zones. The most remarkable and extensively studied examples include Mesozoic to Cenozoic mélanges in the circum-Pacific realm, such as the Franciscan complex, California and Oregon (e.g., Aalto, 1981; Cowan, 1974; Cowan and Page, 1975; Fox, 1976; Gucwa, 1975; Hsü, 1968; Kleist, 1974; Platt, 1975; Platt et al., 1976; Ring, 2008; Tarduno et al., 1985; Wakabayashi, 1999, 2008, 2011, 2012), the Shimanto belt, Japan (e.g., Osozawa et al., 2009; Ueda et al., 2000; Ujiie, 2002; Ujiie et al., 2000; Yamamoto et al., 2009), the Tararua Range and the Balloon mélange, New Zealand (e.g., Jongens et al., 2003; Orr et al., 1991), the Chilean forearc in the Andean region (e.g., Glodny et al., 2005; Wilson et al., 1989), or those of the Alpine–Himalayan belt (e.g., Burg et al., 2008;

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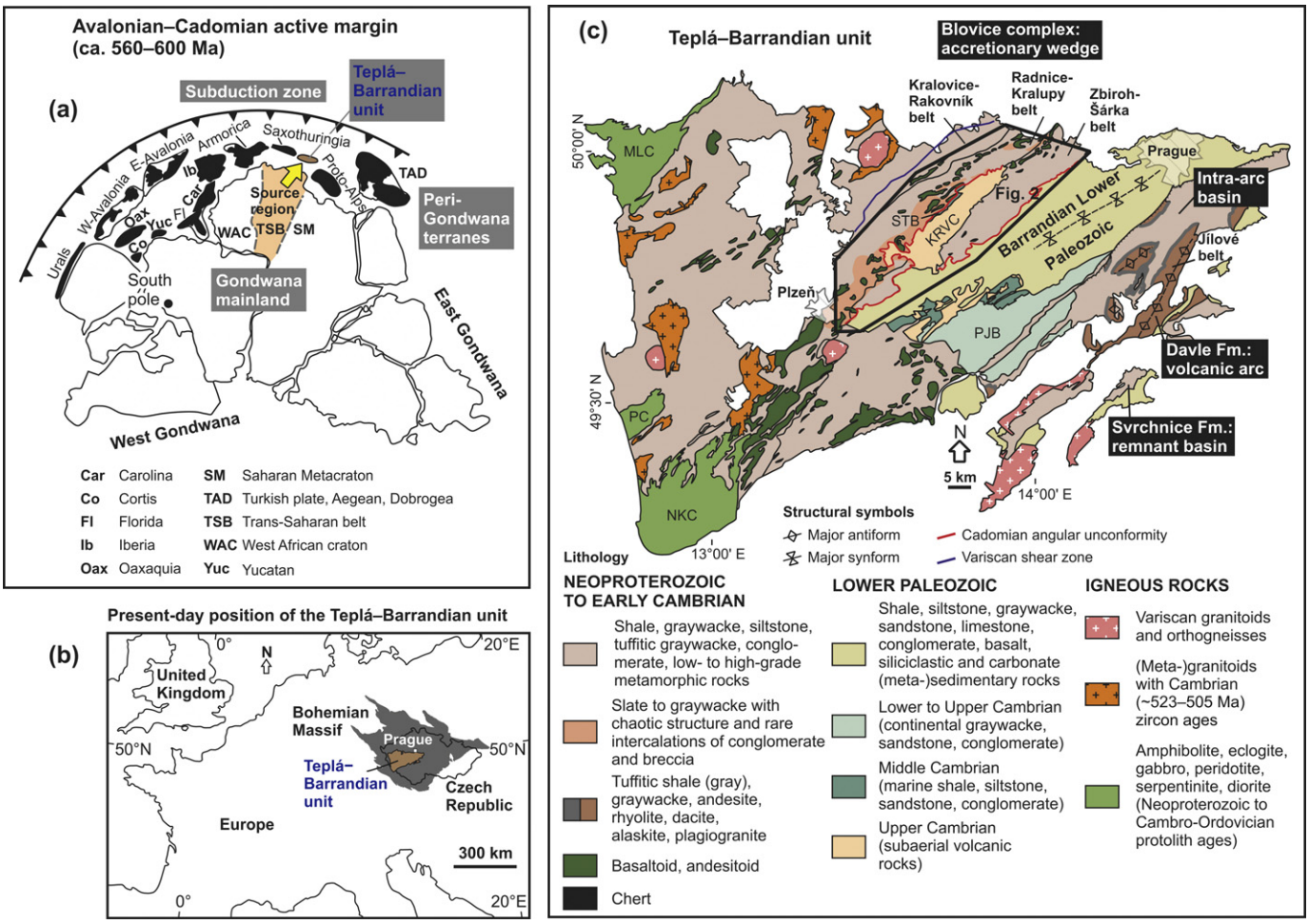

Fig. 1. (a) Inferred paleogeographic position of the Teplá–Barrandian unit within the Avalonian–Cadomian belt on the northern active margin of Gondwana during the late Neoproterozoic (after Linnemann et al., 2004 and Drost et al., 2011). (b) The present-day position of the Teplá–Barrandian unit in the central Bohemian Massif. (c) Simplified geologic map of the Teplá–Barrandian unit; redrafted from Geologic map of the Czech Republic 1:500,000 published by the Czech Geological Survey, Prague, 2007. KRVC – Křivoklát–Rokycany volcanic complex, MLC – Mariánské Lázně complex, NKC – Neukirchen–Kdyně complex, PC – Poběžovice complex, PJB – Příbram–Jince basin, STB – Skryje–Týřovice basin.

Festa, 2011; Festa et al., 2010b; Perotti et al., 2012). In contrast, earlier, Precambrian mélanges, which would corroborate the operation of modern plate tectonic processes, have been only rarely documented and examined in detail. The Precambrian examples include Mesoproterozoic to Neoproterozoic ophiolitic mélanges of the Arabian–Nubian shield (Al-Shanti and Gass, 1983; El Bahariya, 2012; Shackleton et al., 1980), blueschist-bearing mélanges of the Bou Azzer inlier, Anti-Atlas Mountains, Morocco (Hefferan et al., 2002), and tectonic mélange in the Schreiber–Hemlo greenstone belt of the Superior province, Canada (Polat and Kerrich, 1999).

As the composition, geometry, and internal structure vary greatly among the known examples of supra-subduction zone mélanges, so too do the inferred mélange-forming processes. In supra-subduction zone settings, mélanges have been interpreted as a result of: (1) gravitational sliding and disruption of semi-consolidated sediments to produce olistostromes (e.g., Cowan, 1985; Festa et al., 2010a,b; Hsü and Schlanger, 1971; Marroni and Pandolfi, 2001; Page and Suppe, 1981; Pini, 1999), (2) mud or serpentinite diapirism governed by lateral and vertical density contrasts (e.g., Camerlenghi and Pini, 2009; Codegone et al., 2012a,b; Lash, 1987; Orange, 1990), (3) tectonic mixing due to variable material displacement paths within accretionary wedges and subduction channels (Cloos, 1982; Cloos and Shreve, 1988a,b; Wakabayashi, 2011), and (4) deformation and movement along broad tabular fault or shear zones that commonly cut across accretionary wedges (Wakabayashi, 2011).

This paper supplements the scarce information on Precambrian mélanges with a detailed study of sedimentary and tectonic mélanges newly recognized in the Cadomian basement of the Teplá–Barrandian unit, Bohemian Massif (Fig. 1). These mélanges define a distinct lithotectonic belt which consists of abundant slivers of ocean floor and lenses of chert and limestone mixed with shale to graywacke matrix (the Radnice–Kralupy belt, RKB in Fig. 2) and which resembles in many aspects the classic Franciscan Complex of California and Oregon. After a brief introduction to the geologic background and basic petrography of the mélange rocks, we describe five areas representing an upper to lower structural levels of the mélange belt. We also summarize the existing geochronologic information from this belt and present new U–Pb zircon ages that surprisingly indicate an extended time span of the mélange formation lasting from the late Neoproterozoic until the early Cambrian. Finally, we use this Barrandian case example as a basis for discussion of the mélange formation and accretionary processes in this ancient, Precambrian to early Cambrian active margin setting in comparison with modern suprasubduction zone environments.