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Late Miocene seep-carbonates and fluid migration on top of the Montepetra intrabasinal high (Northern Apennines, Italy): Relations with synsedimentary folding

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ABSTRACT

During the Miocene, hydrocarbon seep-carbonates located atop intrabasinal highs and associated with sediment instability, formed commonly at the deformation front of the Northern Apennine collisional orogen. The parallelism between the structural trend and the distribution of seep-carbonates suggests a close relationship between tectonics and gas/fluid emission.

The "Montepetra intrabasinal high" was formed during the closure stage of the foredeep, being related to the synsedimentary growth of an anticline. Field geometry suggests that detachment folding was the leading mechanism of anticline growth and synsedimentary instability along the anticline flanks. Ten different bodies of seep-carbonates occur in the Tortonian–early Messinian sediments: nine in the hinge zone and one in the southern backlimb of the anticline.

Foraminiferal study, geochemistry, facies investigation and the three-dimensional geometry of carbonate bodies with respect to the encasing terrigenous sediments indicate a protracted (late Tortonian–early Messinian) activity of fluid migration with re-mobilization and ascent of sediments from the core of the anticline, stabilization of chemosynthesis-related communities, and in-situ brecciation.

Seepage atop the intrabasinal high was fed by different circuits: one related to the compaction-dewatering of shallow (Tortonian–early Messinian) sediments, and a deeper one related to the deformation of the anticline core and to the activity of detachment surfaces and of faults propagating through the sedimentary cover.

1. Introduction

Migration and expulsion of hydrocarbon-rich pore fluids are common processes in accretionary wedges resulting from sediment offscraping and tectonic compaction (Orange et al., 1999; Delisle et al., 2002; Diaz del Rio et al., 2003; Johnson et al., 2003; Mazzini et al., 2004). Fluid expulsion at the sea floor is evidenced by: 1) specialized seep ecosystems (e.g., Sibuet and Olu, 1998; Van Dover et al., 2003), 2) authigenic carbonates (e.g., Aiello, 2005; Teichert et al., 2005; Campbell et al., 2008), 3) enhanced slope instability (Bohrmann et al, 2002), and 4) mud diapirs and volcanoes (Orange and Breen, 1992; Greinert et al., 2001; Kastner, 2001; Torres et al., 2002; Mazurenko and Soloviev, 2003; Moerz et al., 2005). Fluid emission along active continental margins could be located in erosive structures, such as canyons, head zones and scars of slides and slumpings (Duperret et al., 1995; Von Rad et al., 2000; Majima et al., 2005), or on relatively elevated structures, such as diapir-related mounds and mud volcanoes (Lance et al., 1998; Aloisi et al., 2000; Kopf et al., 2001; Mazurenko et al., 2002; Han et al., 2004), and at the top of anticlines and fault-controlled ridges (Lallemand et al., 1992; Suess et al., 1998, 1999; Orphan et al., 2004).

Intrabasinal ridges and breached anticlines serve to trap fluids and gases through the sediment column and also provide local extensional environments at their crests for fluid expulsion and deposition of authigenic carbonates to take place (Reed et al., 1990; Trehu et al., 1999; Wiedicke et al., 2002). Methane accumulation in the hinge zone may form a hydrate seal, trapping methane in underlying strata. Seal rupture by tectonic activity or sediment failure allows escape of methane and contributes to fluid expulsion. A substantial amount of fluids is therefore released in a short time: interstitial fluid overpressure might induce in-situ fluidization of sediments and the onset of mud/sand volcanoes; moreover the associated lowering in shear strength of sediments cause slope instability and mass transport processes.

Fossil seep-carbonates are largely represented in the sedimentary record of accretionary and orogenic wedges, often associated with sediment instability and mass transport bodies (Goedert and Squires, 1990; Clari et al., 1994; Terzi et al., 1994; Kelly et al., 1995; Conti and

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Fontana, 2002; Schwartz et al., 2003; Campbell, 2006; Conti et al., 2007), and with mud diapirs/volcanoes (Accaino et al., 2007; Camerlenghi and Pini, 2009).

During the Miocene, seep-carbonates located atop intrabasinal highs and associated with sediment instability, formed commonly in the inner part of the foredeep, at the front of the Northern Apennine paleo-wedge. They are located in two different depositional settings: (1) in pelitic intervals included in Langhian–Serravallian basin-plain turbidites, or (2) in slope hemipelagites (Langhian–early Messinian) capping turbidites in proximity to the deformational fronts (Conti and Fontana, 2002).

The Montepetra intrabasinal high (Figs. 1 and 2) is a good representative of the second depositional setting. It was formed during the closure stage of the foredeep, being related to the

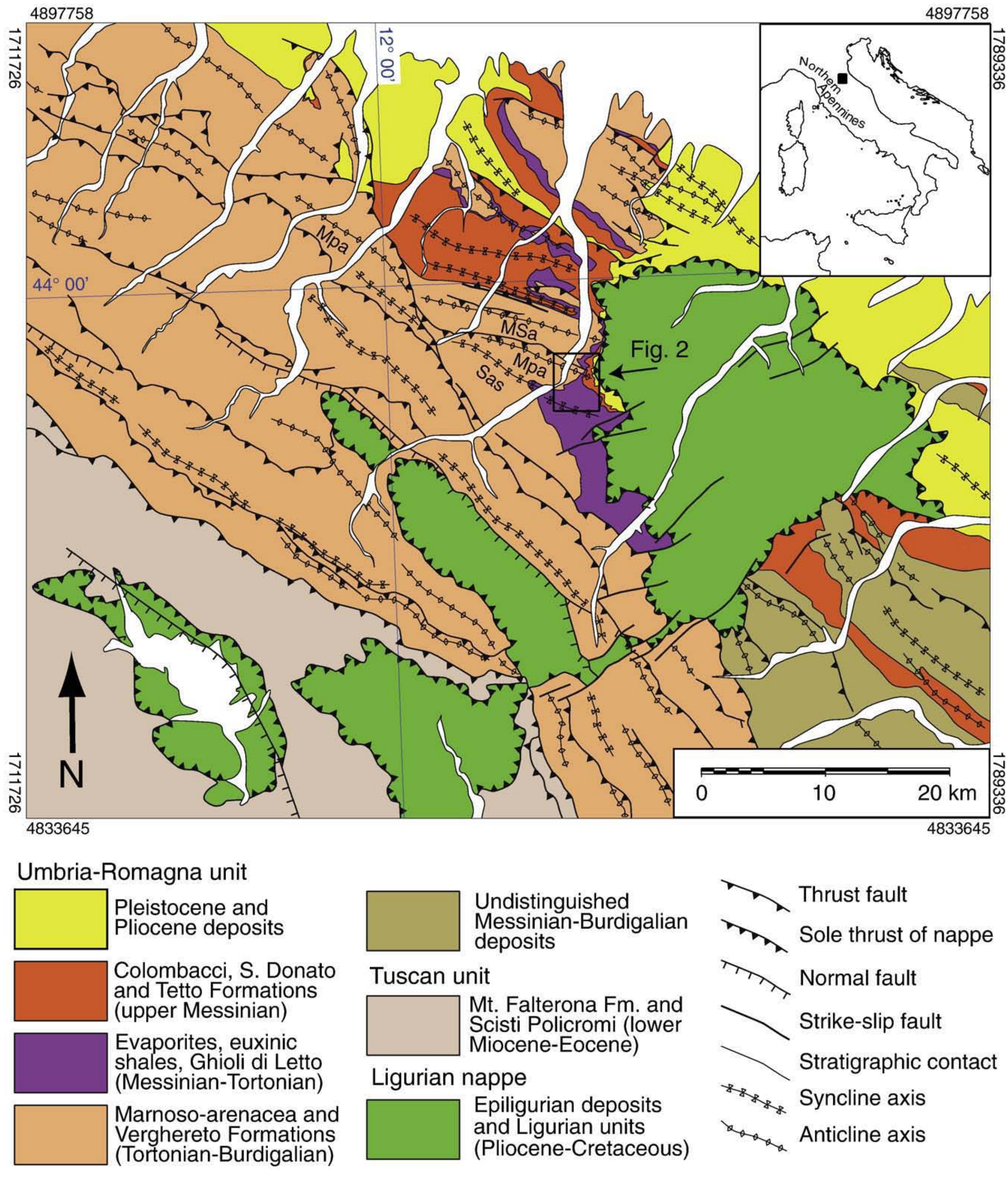

Fig. 1. Simplified geological map of the Romagna–Marche Apennines. Map coordinates are expressed in metres, system: SI 1940 Rome. Geographic coordinates are referred to Greenwich (UTM, ED50). The box shows the studied area (outline of Fig. 2). Key to the tectonic structure labels: Sas = Sapigno syncline; Mpa = Montepetra anticline and its possible NW-ward continuation in the hanging wall of the Montepetra thrust; MSa = Mercato Saraceno anticline.
Main sources: Capozzi et al. (1991), Cerrina Feroni et al. (2002), Conti (2002b), and Lucente and Pini (2003).