



## **Miocene seep-carbonates as indicators of fluid migration in the northern Apennines (Italy)**

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In the Miocene satellite and foredeep basins of the northern Apennines, numerous carbonate bodies were identified by specific palaeoecological, sedimentological, compositional and isotopic features as products of the microbial oxidation of methane-rich fluids. These seep-carbonates occur in large turbiditic bodies (Mt. Cervarola and Marnoso-arenacea Formations) and in slope hemipelagites (Vicchio and Verghereto Marls, and Ghioli di letto mudstones). Dominant rock types are calcilititic limestones, marly limestones, calcareous marls and calcarenites. Carbonates exhibit typical  $^{13}\text{C}$ -depleted signatures indicative of methane oxidation.

Several characteristics allow two types of seep-carbonates to be distinguished in the field (type 1 and 2). The type 1 is composed of a horizontal repetition of decametric to heptometric carbonate bodies, lenses and pinnacles. The basal portions of these huge bodies are strongly brecciated, made up of intraformational and rarely extraformational polygenic breccias. The type 2 is made of numerous and small marly-calcareous lenses, irregular column-like bodies aligned along bedding strikes, or horizontally and vertically scattered and not related to a precise stratigraphic level. Many of them consist of several lenticular units vertically stacked and separated by thin pelitic levels, thus suggesting periodic growth.

Carbon isotope measurements show that carbonates from type 1 and 2 are typically depleted in  $^{13}\text{C}$  but the amount of depletion seems to differ between them. Therefore type 1 seep-carbonates appear significantly depleted in  $\delta^{13}\text{C}$  ( $\delta^{13}\text{C}$  ranging from -30‰, to

-55‰, relative to the PDB standard) while type 2 seep-carbonates are only moderately depleted ( $\delta^{13}\text{C}$  varying from -10‰ to -20‰, relative to the PDB standard). Concerning oxygen isotopic measurements type 1 seep-carbonates seem to be enriched in  $\delta^{18}\text{O}$  ( $\delta^{18}\text{O}$  ranging from 1‰ to 6‰, relative to the PDB standard) whereas type 2 seep-carbonates show a more scattered range ( $\delta^{18}\text{O}$  varying from -3.00‰ to 2‰, relative to the PDB standard). Benthic and planktonic foraminifera studies are also performed to investigate paleoenvironmental settings and the effect of methane seepage on faunal assemblage.

Our presentation will draw attention to the distinctive characters of the two types of seep-carbonates. In particular we discuss the isotope geochemistry, the mineralogy, the geometry in context with the precipitation and recrystallisation processes of the carbonates, the origin of carbon rich fluids and with the mechanisms of expulsion (diffused or focused). Possible relationships with gas hydrate destabilization processes are also discussed.