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Hudson submarine canyon head offshore New York and New Jersey: A physical and geochemical investigation

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ABSTRACT

Hudson Canyon is the largest shelf-sourced canyon system off the east coast of the United States, and hosts a productive ecosystem that supports key fisheries. Here we report the results of a multi-year interdisciplinary study of the geological, geochemical, and physical oceanographic features and processes in the canyon that underpin that ecosystem. High-resolution multi-beam bathymetric and backscatter data show that the contrasting morphology of the two perpendicularly oriented branches at the head of the Hudson Canyon is indicative of different states of geomorphological activity and sediment transport. Tightly spaced ridges and gullies extend perpendicularly towards the canyon axis from the canyon walls. Numerous depressions are found at the base of the canyon walls or along the canyon axis at depths from 300 m to 600 m. Elevated concentrations of dissolved methane in the water column, where the highest density of depressions occur, suggests that methane is actively venting there. The topography and reflective floors of circular depressions in canyon walls and their association with methane maxima suggest that these represent active methane gas release-collapse pockmarks with carbonate floors. Patterns of irregular, low-relief, reflective depressions on the canyon floor may also represent methane release points, either as gas release or cold-seep features. The presence of methane maxima in a region of strong advective currents suggests continuous and substantial methane supply. Hydrographic observations in the canyon show that multiple layers of distinct inter-leaved shelf (cold, fresh) and slope (warm, salty) water masses occupy the head of the canyon during the summer. Their interactions with the canyon and with each other produce shifting fronts, internal waves, and strong currents that are influenced by canyon topography. Strong tidal currents with along-canyon-axis flow shear help to drive the advection, dispersion and mixing of dissolved materials in the water column that likely help support the rich canyon ecosystem.

1. Introduction

A vast ocean frontier in an early stage of exploration lies at the doorstep of the New York–New Jersey metropolitan area seaward of the Hudson River and is dominated by a submarine valley and canyon which represents the so called Hudson Canyon system (Fig. 1). The Hudson River channel extends about 500 km southward from its watershed in the Adirondack Mountains to New

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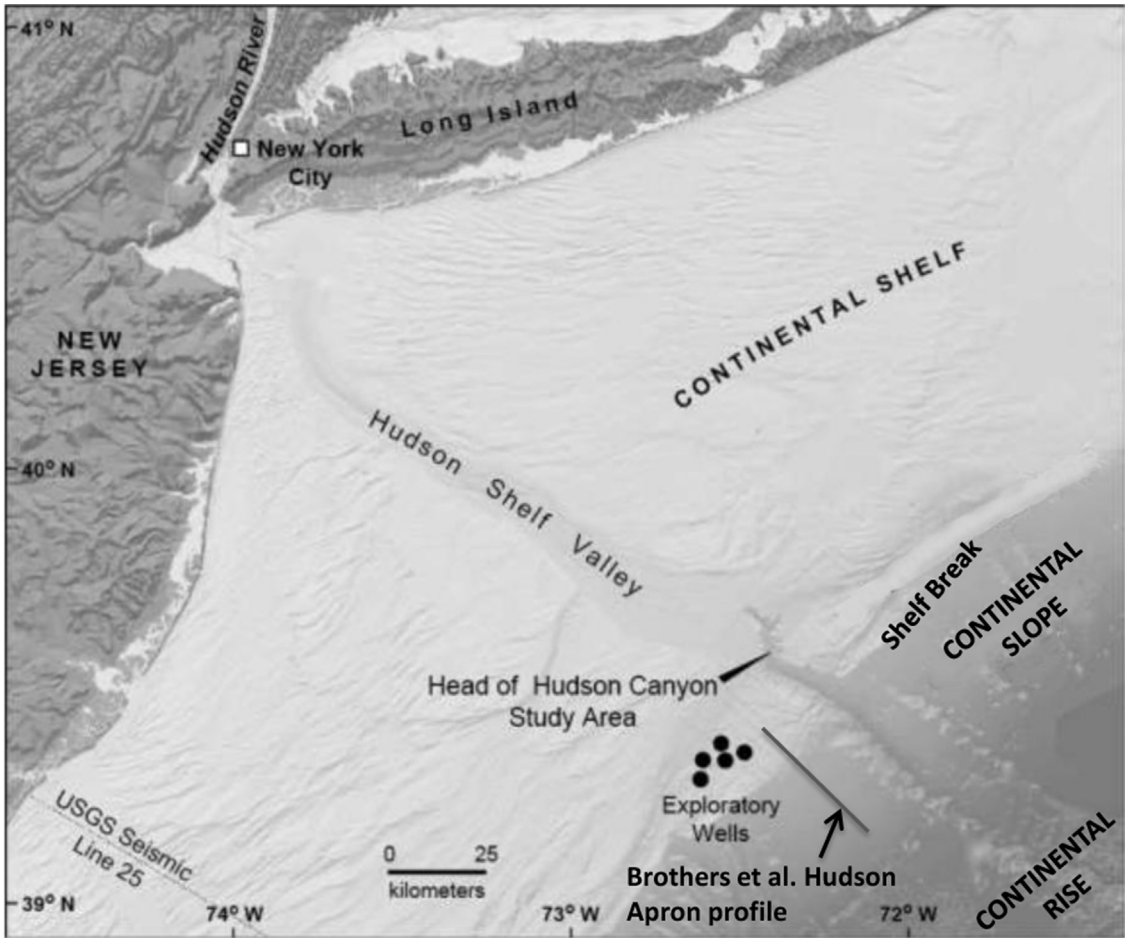

Fig. 1. Regional map of the continental margin off New York and New Jersey showing study area at head of Hudson Canyon where the canyon indents the outer edge of the continental shelf about 185 km (100 nm) seaward of the mouth of the Hudson River in New York harbor. A shallow trough, the Hudson Shelf Valley connects the canyon head to the river mouth. Positions of exploratory oil wells, Brothers et al. (2014) Hudson Apron profile (Fig. 4), and a multi-beam seismic profile (U.S. Geological Survey Line 25) are shown.

York Bay where it links with the submarine Hudson Shelf Valley (HSV). The HSV extends southeast as a shallow trough (5–40 m below the surrounding shelf surface; width ~4–16 km; mean axial seaward inclination ~1°) about 150 km across the continental shelf to a shelf edge delta complex near the 80 m isobath (Ewing et al., 1963; Butman et al., 2003; Thieler et al., 2007). Just seaward of where the HSV ends, the Hudson Canyon begins as a smooth semi-circular indentation at the seaward edge of the shelf (water depth ~80–100 m; Fig. 1). The canyon continues seaward, cutting through the continental shelf and slope for ~50 km as a gorge whose floor ranges from water depths of 120 m to 2000 m with walls attaining a maximum relief of about 1200 m and rim-to-rim width of ~5–10 km. The mean inclination of the axis in this stretch of the canyon is about 5° (Pratson and Haxby, 1996). The canyon extends another ~450 km down the continental rise (water depth down to ~5000 m; mean seaward inclination ~1°) to the Hatteras Abyssal Plain, bridging the Hudson River channel and the deep ocean basin (Heezen and Tharp, 1957).

Hudson Canyon is the largest of 23 major shelf-sourced submarine canyons that incise the seaward edge of the continental shelf on the eastern U.S. continental margin between the Canadian border and Virginia, and is comparable in size to Monterey Canyon, the largest canyon on the western U.S. margin. Monterey Canyon, designated by the National Oceanic and Atmospheric Administration (NOAA) as the Monterey Bay National Marine Sanctuary, has been extensively explored and is the subject of an initiative to improve ecosystem-based management of its resources (Brown et al., 2011). Conversely, management of the Hudson Canyon system remains limited by the lack of appropriate observations that would allow us to address interdisciplinary questions concerning the canyon's geology, physics, geochemistry, and biological productivity.

The head of Hudson Canyon is highly productive and is of interest to commercial and recreational fisheries for a number of reasons. It is recognized as a commercial fishing "hot spot" that contains essential habitats for a number of finfish species (summer flounder, silver and red hake, black sea bass, butterfish, tilefish), long fin squid, and shellfish (lobster, deep sea red crabs) that contribute to local and regional commercial fisheries. Commercial catches in the surrounding fisheries statistical area (SA616) in the period 2008–2012 suggest a strong and persistent role of this canyon in enhancing fisheries on the surrounding shelf (NEFMC, 2014). The northern terminus of the canyon has yielded particularly large catches (Fig. 2). Corroborating the "hot spot" status of the canyon based on industry catches, fisheries-independent catch-per-unit-effort (CPUE) data from the Northeast Fisheries Science Center (NEFSC) spring trawl survey suggest substantially higher densities of several managed fisheries species than on the shelf in general (Table 1). Limited non-fisheries observations at higher trophic levels suggest increased concentrations of krill attracting larger numbers of marine mammals in Hudson and other east coast canyon systems (Greene et al., 1988; Hooker et al., 1999; Waring et al., 2001). Finally, the New England Fisheries Management Council found that the Hudson Canyon may merit