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Hatteras Transverse Canyon, Hatteras Outer Ridge and environs of the U.S. Atlantic margin: A view from multibeam bathymetry and backscatter

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A B S T R A C T

Previously unknown features in Hatteras Transverse Canyon and environs were recently mapped during multibeam surveys of almost the entire eastern U.S. Atlantic continental margin. The newly identified features include (1) extensive landslide scarps on the walls of Hatteras Transverse and Hatteras Canyons, (2) an area of multiple landslide deposits that block lower Hatteras Transverse Canyon, (3) a large depositional feature down-canyon from the landslide deposits that rises 100 m above the uppermost Hatteras Fan and has buried the transition from the mouth of Hatteras Transverse Canyon to uppermost Hatteras Fan, (4) a zone of cyclic steps on upper Hatteras Fan that suggests supercritical turbidity currents performed a series of hydraulic jumps and formed large upstream-migrating bedforms, (5) several knickpoints in the channel thalwegs of both Hatteras Transverse Canyon and Hatteras Canyon, one 40 m high, that suggest both canyon channels are out of equilibrium and are in the process of readjusting, either to the channel blockage by the extensive landslide deposits or by a readjustments to increased sedimentation during the last eustatic lowstand, (6) a large area of outcrop on the lower margin between Pamlico and Hatteras Canyons that previously was interpreted as an area of slumps, blocky slide debris and mud waves, (7) headward erosion in the head region of Hatteras Transverse Canyon where it has intercepted the lowest reaches of Albemarle Canyon channel as well as headward erosion in a small side channel that has eroded into Hatteras Outer Ridge and (8) sections of bedforms on Hatteras Outer Ridge that are partially buried by sediment from Washington–Norfolk Canyon channel as well as by sediment transported from Hatteras Abyssal Plain. The newly discovered features add a new level of detail to understand the recent processes that have profoundly affected Hatteras Transverse Canyon, Hatteras Canyon and, to a lesser degree, Hatteras Outer Ridge.

1. Introduction

A submarine canyon that strikes roughly parallel, not roughly perpendicular, to isobaths on a continental margin is a very rare feature in the world ocean. In fact, transverse submarine canyons are so rare that the review of the global distribution and geomorphologies of submarine canyons by Harris and Whiteway (2011) does not mention one submarine canyon that strikes transverse to a margin. However, a few such canyons; e.g., Ameghino Transverse Canyon and Almirante Brown Transverse (sometimes referred to as the Patagonia Canyon) on the Argentine margin (Lonardi and Ewing, 1971; Hernández-Molina et al., 2009; Lastras et al., 2011) and Valencia Valley in the northwestern Mediterranean Basin (Palanques and Maldonado, 1985; Amblas et al., 2011), have been described in some detail. In all of these examples, including Hatteras Transverse Canyon on the eastern U.S. Atlantic continental margin (Fig. 1), there is either a sediment drift (Ameghino, Almirante Brown and Hatteras Transverse Canyons) or a basement high (Valencia Channel) that has deflected sediment transport away from downslope to a cross-slope trend. The existence and uniqueness of Hatteras Transverse Canyon has been known since the late 1960s. Although, since the advent of modern commercially available multibeam echosounders (MBES) in the 1960s, Hatteras Transverse Canyon and the adjacent Hatteras Outer Ridge have not until now been mapped with a MBES. A modern deep-water MBES can map large areas of the seafloor with swaths of ~50 m/sounding spacing and even denser co-registered acoustic backscatter data that provide 3-dimensional digital views of the seafloor relief and the acoustic response of the seafloor to the MBES frequency. The area of this study (Fig. 2) was completely surveyed with a 12-kHz MBES during mapping of the bathymetry of the entire U.S. Atlantic continental margin between the 1000 and 5500 m isobaths as part of the U.S. Law of the Sea Extended Continental Shelf project (Gardner et al., 2006). The objective of this work is to use the new multibeam data to provide a three-dimensional quantitative description of the seascape at 100 m/pixel resolution, which is much higher than

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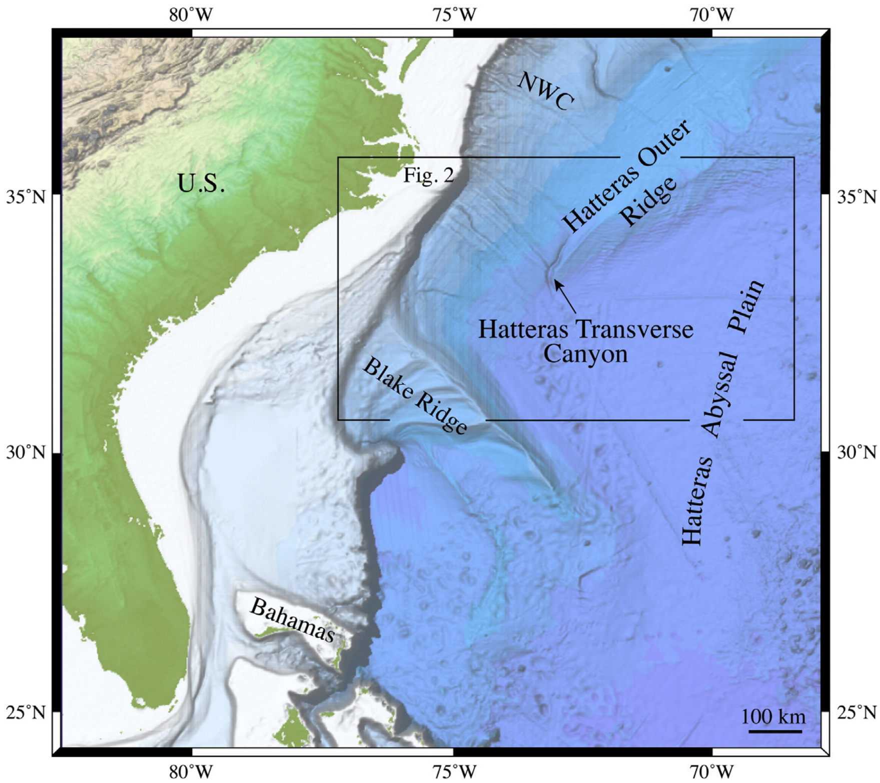

Fig. 1. Location of Hatteras Transverse Canyon, Hatteras Outer Ridge and Hatteras Abyssal Plain on the U.S. Atlantic continental margin. Bathymetry is predicted bathymetry of Smith and Sandwell (1997, v. 17.1). NWC is Norfolk–Washington Canyon. Black rectangle is the location of Fig. 2.

has been done to date for this area, and to identify various smaller-scale features that have until now not been described from this area. The digital terrain model (DTM), together with simultaneously collected co-registered acoustic backscatter, allow a better understanding of the processes that formed and modified the present seafloor than was provided by the older non-MBES data.

The traditional (pre-MBES) description of the continental margin southeast of Cape Hatteras is that of a relatively narrow 30- to 60-km-wide continental shelf, an ~95-km-wide continental slope and a broad ~375-km-wide continental rise that merges with Hatteras Abyssal Plain at approximately the 5400-m isobath. The slope and rise were constructed by deposition from turbidity currents (Drake et al., 1968; Emery et al., 1970; Pilkey and Cleary, 1986) and large mass-transport deposits (Embley and Jacobi, 1977; Embley, 1980; Twichell et al., 2009) that were subsequently modified by southward-flowing geostrophic currents that reworked the sediment (Heezen et al., 1966; McCave and Tucholke, 1986). The margin in the area of Hatteras Transverse Canyon is dominated by a series of submarine canyons and their channel extensions (here called canyon channels), especially Albemarle, Hatteras and Pamlico Canyons and to a lesser extent Washington–Norfolk Canyon (Fig. 2) and their associated canyon channels (Rona et al., 1967; Newton and Pilkey, 1969), but also by numerous smaller unnamed canyons and canyon channels. These canyons and canyon channels trend directly downslope until they are captured by Hatteras Transverse Canyon, located immediately upslope of Hatteras Outer Ridge that has served as an obstacle to continued downslope flow of turbidity currents. Hatteras Outer Ridge, a large late Tertiary to Late Pliocene sediment drift, has diverted sediments to the southwest that were initially transported directly downslope through the canyons and canyon channels to the Hatteras Abyssal Plain. The diversion of sediments formed Hatteras Transverse Canyon and redirected sediment to a more southerly location on Hatteras Fan (Cleary and Conolly, 1974). The mouth of Hatteras Transverse Canyon emerges from the southwestern end of Hatteras Outer Ridge, where sediment has once again been diverted to the southeast by the large failure masses of Cape Fear and Cape Lookout Slides (Fig. 2) and eventually emerged onto Hatteras Fan as a series of small distributaries that spread out onto the southern Hatteras Abyssal Plain.

Work in the 1960s identified Hatteras Transverse Canyon and Hatteras Outer Ridge as somewhat anomalous features and various interpretations derived from single-beam echosounder and subbottom-profiler data were offered to explain their character. The bathymetry of Hatteras Transverse Canyon was first described by Rona et al. (1967) based on about 30 wide-angle single-beam echosounder profiles. They also produced a map of the lower reaches of Hatteras and Pamlico Canyons in the area where Hatteras Transverse Canyon captures the two canyons. They noted that the course of Hatteras Transverse Canyon roughly parallels rather than trends perpendicular to the regional isobaths, as is more typical of the other canyons and canyon channels in the region. Subsequent studies of this area using wide-angle single-beam echosounders and subbottom profilers were made by Rona and Clay (1967), Newton and Pilkey (1969), Cleary and Conolly (1974), Cleary et al. (1977), Bunn and McGregor (1980) and Pratson and Laine (1989), with seismic-reflection profiles by Tucholke and Laine (1982) and with GLORIA long-range sidescan-sonar images and widely spaced seismic profiles by Popenoe and Dillon (1996). These studies outlined the general characteristics of lower Hatteras Canyon but with widely dispersed tracklines and varying qualities of bathymetry. Rona et al. (1967) related the trend of lower Hatteras Canyon to a deflection of downslope sediment transport by Hatteras Outer Ridge. The bathymetry of Hatteras Outer Ridge was first mentioned by Heezen et al. (1959) and later investigated by Rona et al. (1967), Rona (1969), Asquith (1979), Tucholke and Laine (1982), Mountain and Tucholke (1985) and Locker and Laine (1992). Rona et al. (1967) suggested the formation of both Hatteras Transverse Canyon and Hatteras Outer Ridge, as well as bedforms on lower Hatteras Canyon (so-called "lower continental rise hills" in the descriptions from the 1960s) were due to current-controlled sedimentation related to the