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Research Article

Mapping Onland River Channels up to the Seafloor along Offshore Cide-Sinop in the Southern Black Sea from the Perspective of the Black Sea Flooding

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Abstract

In order to investigate the submarine morphology of offshore Cide-Sinop from the perspective of the Black Sea flooding, the rivers, submarine channels and some spatial data were extracted by using General Bathymetric Chart of the Oceans (GEBCO-2014) which is a seamless digital elevation and bathymetry grid (DEM), and Geographic Information System (GIS) software tools. The accuracy of extracted land rivers were controlled with 1/25K topo-maps by using buffer overlay method. The comparisons affirmed that the rivers are on ratio of 75% in 0-400 meters buffer distance. The derived network with a total of 2238 km length indicates that there is a dendritic drainage pattern with the flow direction from south to the north extending from land to shelf plain, shelf break and converging toward the abyssal plain respectively in the study area. However, seismic profiles do not indicate any recent delta deposits on the shelf plain. The only some prograded delta deposits are determined at the shelf break in a limited area, where they coincide with the submarine channels derived in this study. These deposits are truncated from their top by an erosional surface which extends over the whole shelf plain. These results indicate that the derived submarine channels do not represent the current flow pattern offshore Cide-Sinop. Instead, they illustrate paleochannels that should be active during the last lowstand time, before the Black Sea Flood and their sedimentary influx should also control the developments of canyons located at the shelf edge at that time. However, the most of the canyons located on the shelf slope are under the influence of both submarine erosion and active tectonics at present.

Keywords: Digital Elevation Model, Geographic Information System, Submarine Morphology, Paleochannel Network, Passive Canyons, Offshore Cide-Sinop

Introduction

Objectives, study area, Black Sea last lowstand time

The rivers originate from the mountains, flow through the plains and terminate at the sea forming deltas but indeed, river channel systems exist beyond land into the sea. In recent studies, DEM and DEM-derived products (spatial data) are used to determine of land and submarine morphology such as Onland Rivers, submarine channels, canyons, depth contours and slope by using GIS software tools. These studies raise our understanding about the relation between present-day onland river systems and marine channel systems and processes (i.e. Pratson and Ryan 1996; Alpar et al., 2004; Kundu and Pattanaik 2011a, 2011b; Harris et al. 2011, 2014; Gazioğlu et al., 2014; Varghese and Manoj 2017). The focus of this study is to analyze the land rivers and submarine channels in the Cide-Sinop region by using a global DEM, GIS analysis tools and seismic reflection sections (Figure 1). We aim to understand not only current environment conditions but also paleoenvironment conditions for sedimentary evolution particularly in relation to sea level changes at the last sea level lowstand time. Because, the Black Sea has been subjected to very spectacular sea level and environmental changes driven by global glaciation and deglaciation episodes in the Quaternary. During the last glacial period when the global sea level fell below the level of the sill of Bosphorus, it was isolated from the Mediterranean Sea and became a freshwater lake (Neoeuxinian phase, 22–9 kyr BP, Degens and Ross 1974). In this period, a large portion of the modern continental shelf areas of the Black Sea were exposed to subaerial erosion and excavated by rivers, until at about 10–9 kyr BP. Then, glacial meltwater filled the Black Sea Lake and drowned the shelf areas (Degens and Ross 1974; Aksu et al. 1999). Ryan et al. (1997a; 1997b) suggested that this invasion occurred by a catastrophic flood and rapid transgression and submerged the exposed continental shelf area to a depth of more than 100 m lower than the present level of the Black Sea at 7150 yr. Ballard et al. (2000) mapped a paleo-shoreline at −155 m by using deep submergence technologies along the Black Sea shelf (Figure 1).

During the low stand time (during the last glacial), the northern and western Black Sea is characterized by high sedimentation rates developed by the large rivers of Europe, Danube, Dnieper, Dniester and Bug rivers, as well as an exceptional shelf with (Figure 1; Jaoshvili 2002; Nicholas and Chivas 2016). These rivers discharged directly into the Black Sea (Ianovici et al. 1960; Banu, 1967). They were channelized by the Viteaz and other canyons and were laid down generally beyond the shelf edge (~130 m water depth) down to the abyssal plain (>2000 m water depth). A prominent deep-sea fan complex was build up sediment supply from these rivers which is highly buried now (Winguth et al. 2000). Popescu et al. (2004) identified numerous channels in this area down to -90 m water depth which they are erosive structures that are filled by a thin mud drape (~20-30 m thick) that generally corresponds to the last highstand deposits, and hence no longer visible in bathymetry. At present, these large scale rivers discharge their sediment loads into a lagoonal system; only a small fraction of the suspended load reaches the sea and the canyons near the shelf break are inactive (Winguth et al. 2000; Popescu et al. 2004, 2015; Jipa and Panin 2020).

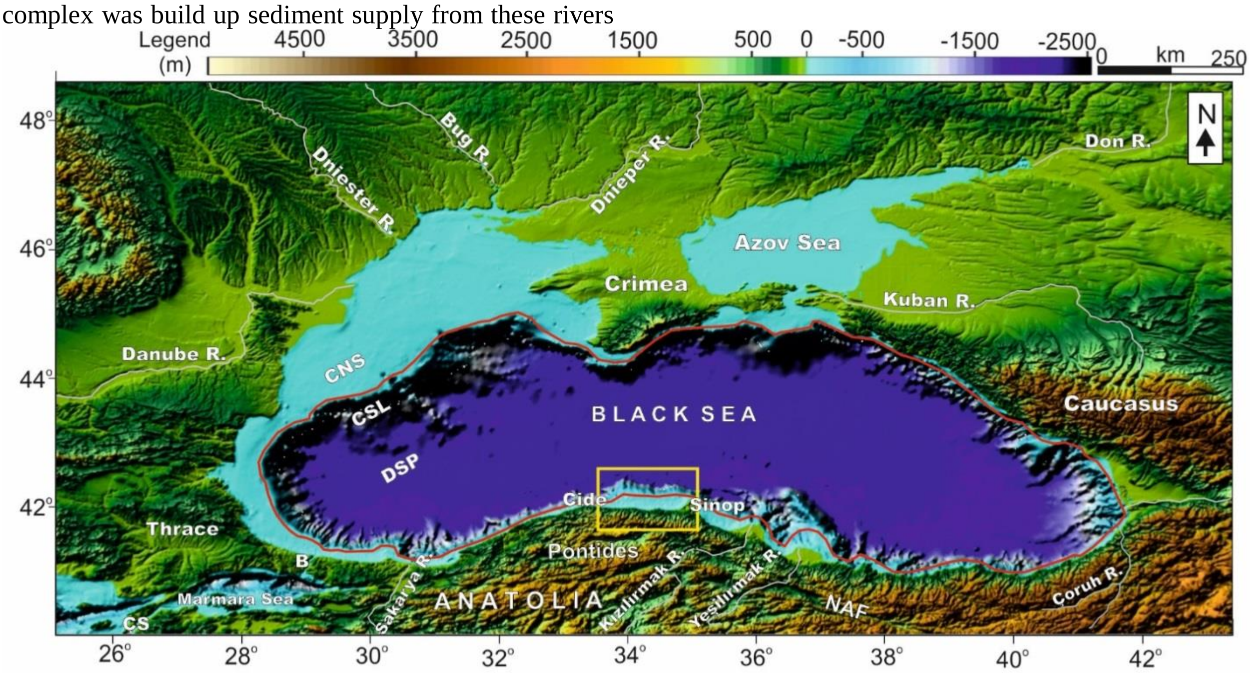

Fig. 1. Study area. Topography and bathymetry map of the Black Sea Region extracted from GEBCO data (http://www.gebco.net/). Paleoshoreline (155 m depth contour) was shown by the red line (Ballard et al. 2000). B Bosphorus, ÇS Çanakkale Strait, NAF North Anatolian Fault, CNS Continental Shelf, CSL Continental Slope and, DSP Deep Sea Plain.

With this perspective, the studies in the southern Black Sea shelf area are very limited to understand the sedimentary evolution in relation to sea level change at the last sea level lowstand time (Okyar and Ediger 1999; Demirbağ et al. 1999; Algan et al. 2002; Gazioğlu, 2017; Ocakoğlu et al. 2018; İşcan et al. 2019). Of these, Cide-Sinop shelf area has particular importance. Because it delineates a relatively large and shallow shelf plain within the narrow southern Black Sea shelf and presents favorable conditions for paleoenvironment studies of this region. Coleman and Ballard (2007) mapped a paleoshoreline offshore Sinop Peninsula at the water depth of -155 m, indicating the transition started to take place before 7400 BP from Neoeuxinian Lake to the Black Sea. They revealed a "typical" beach profile (after Ballard et al. 2000). In addition, they collected well-rounded stones which were probably worked by moving water, either in a riverine, or near-shore marine or lacustrine environment and they interpreted this submerged landscape topography as the remnants of the ancient river channels that flowed through these valleys (after Ballard et al. 2001). Later, Ocakoğlu et al. (2018) made similar observations on the multibeam bathymetry and multichannel seismic reflection data in this area. They interpreted the paleoshoreline varies from −100 to −120 m offshore Cide-Sinop. They mapped a large eroded shelf plain and some morphological features widely sitting upon of this erosional surface at −100 m water depth developed by aeolian and fluvial processes when the area was once a terrestrial landscape. Some prograded delta deposits truncated by their top with the same erosional surface and extended only in a limited area around the shelf break were observed but their continuation toward the inner shelf was not follow on the data. These morphological interpretations figure out an abrupt submergence offshore Cide-Sinop during the last sea level lowstand time. However, the limited multibeam data coverage in Ocakoğlu et al. (2018) study, did not provide much inference to understand the river network during that time both in the inner and outer shelf area.

For this purpose, the authors aimed to extract the detail mapping of the channel system from land to the abyssal plain and analyze the discharging system of land rives both presently and at the last lowstand time of Black Sea. Particularly, the paleoenvironment conditions for sedimentary evolution such as paleoriver network, paleoshoreline and paleocanyons were analyzed from the perspective of the Black Sea flooding. The relations between land rivers, submarine channels and canyons were quantified by derived spatial data using DEM and GIS tools and shallow seismic stratigraphy of Cide-Sinop shelf area.

Black Sea canyons

It is commonly held that sedimentation is focused on the inner shelf during highstands and conversely on the fan during lowstands (Haq et al. 1987). Thus, during the lowstands, the sub-aerial exposure of continental shelf let to the progression of channels of land rivers on the shelf, generally causing the development of canyons. This has long been observed that many submarine canyons were spatially connected to rivers on the continent (Twichell et al. 1982). However, Popescu et al. (2015) classified the Black sea canyons due to the shelf width. While the canyons located at the narrow continental shelf (eastern and southern shelves of the Black Sea) are active during the highstands (at present) that they capture entirely or partially the sediment load brought by rivers into the sea. The canyons located at the large continental shelf (northern and northwestern shelves of the Black Sea) are passive during the highstands (at present) that they discharge their sedimentary load into the lagoons separated by beach barriers from the sea. Due to this classification, the canyons offshore Romania were categorized as passive canyon at present (Popescu et al. 2015; Jipa and Panin 2020) whilst, Caucasian canyons (i.e. Chorokhi Canyon, Sipahioğlu et al. 2013) and Anatolian Black Sea Canyons (i.e. Sakarya Canyon, Yeşilırmak Canyon, Algan et al. 2002; Dondurur and Çiftçi 2007) were categorized as active canyons. Unlike Popescu et al. (2015) study, Jipa and Panin (2020) noticed that the narrow-shelf canyons are active both lowstand and highstand conditions. Under these classifications, we aim to analyze the submarine canyons and their evolution offshore Cide-Sinop in the southern Black Sea shelf due to the sediment transport to this system at present and at last sea level lowstand of Black Sea.

Material and Methods

The base data used in this study consists of the land and bathymetry DEM and the multichannel seismic reflection data. Firstly, the high resolution global bathymetry data such as The European Marine Observation and Data Network (EMODnet) was investigated for the study area. Since the EMODnet data sampling interval was very sparse in the Black Sea, the EMODnet team harmonized GEBCO data with some multibeam data (Thierry et al. 2019). Thus, the final resolution is actually close to GEBCO-2014 grid. In this study, original GEBCO-2014 data was used to extract of spatial data. GEBCO-2014 grid is a digital bathymetric model of the world ocean floor was merged with land topography from the Shuttle Radar Topography Mission (SRTM) (Weatherall et al. 2015). DEM data was downloaded from GEBCO web site (gebco.org) with the geographic coordinates of WGS84 ellipsoid and the rivers, submarine channels and other spatial data were produced by using in-built hydrology tools in ArcGIS 10.5 software. The rivers of 1/25K topo maps which were produced from Turkey General Directorate of Mapping, were used for accuracy assessment of land products.

The multichannel seismic reflection data were collected by the Turkey Petroleum Corporation (TP) in 1991 and subsequently processed and interpreted at the Department of Geophysics, Istanbul Technical University within the framework of a scientific project supported by the Scientific and Technological Research Council of Turkey (TUBITAK). The recording parameters such as number of channels, shot interval, group interval, sampling interval, and record length were selected 240, 30 m, 15 m, 50 m, 2 ms and 7.0 s respectively.

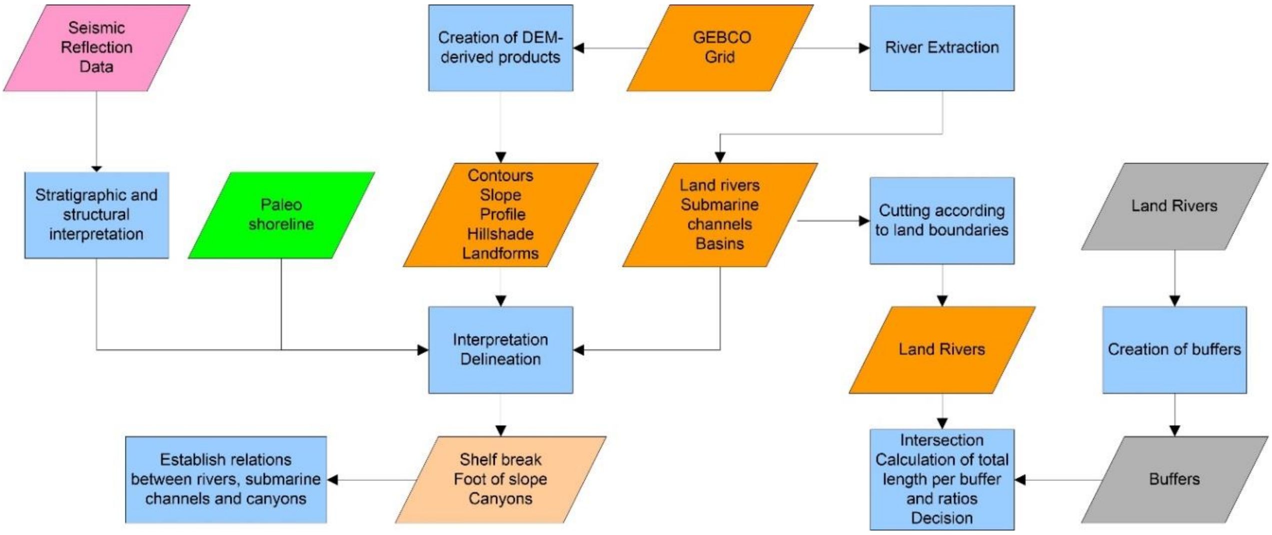

Fig.2. Stream network extraction flowchart.

Processing of data

A methodologic flowchart was presented to process the data in Figure 2. Firstly, the geographic coordinate system of DEM has transformed to UTM 36N of WGS84 datum by using global parameters and DEM resulted with a resolution of 600 m. Extraction of submarine drainage networks, as similarly to land, began with the determining the direction of flow in the DEM pixels by using ArcGIS hydrology tools and ended with conversion to vector streams. Then, the "fill" tool was applied for improving small errors to DEM. This tool determines pixels that are lower than all their neighbors within the DEM. The new values of pixels were recalculated according to neighbor pixel values. Later, the flow direction was determined as the cell of steepest descent from every cell in the DEM by using the "flow direction" tool. The calculated flow direction data pixel values were saved as the value of one of 8 different flow directions (Figure 3a). In the next step, the "flow accumulation" tool was used (Figure 3b). This tool uses flow direction data and produces new data by summing up the number of cells that flow into a specific cell. Rivers and submarine channels were extracted by both using the flow accumulation output grid and applying a threshold upstream cell number of 20. From these grids, stream junctions were calculated and the numerical order of each stream segment was defined according to the Strahler's (1952) method (Figure 4a). The "stream to feature" tool which uses raster rivers, submarine channels data and flow direction data, was used to convert the raster data to vector data.

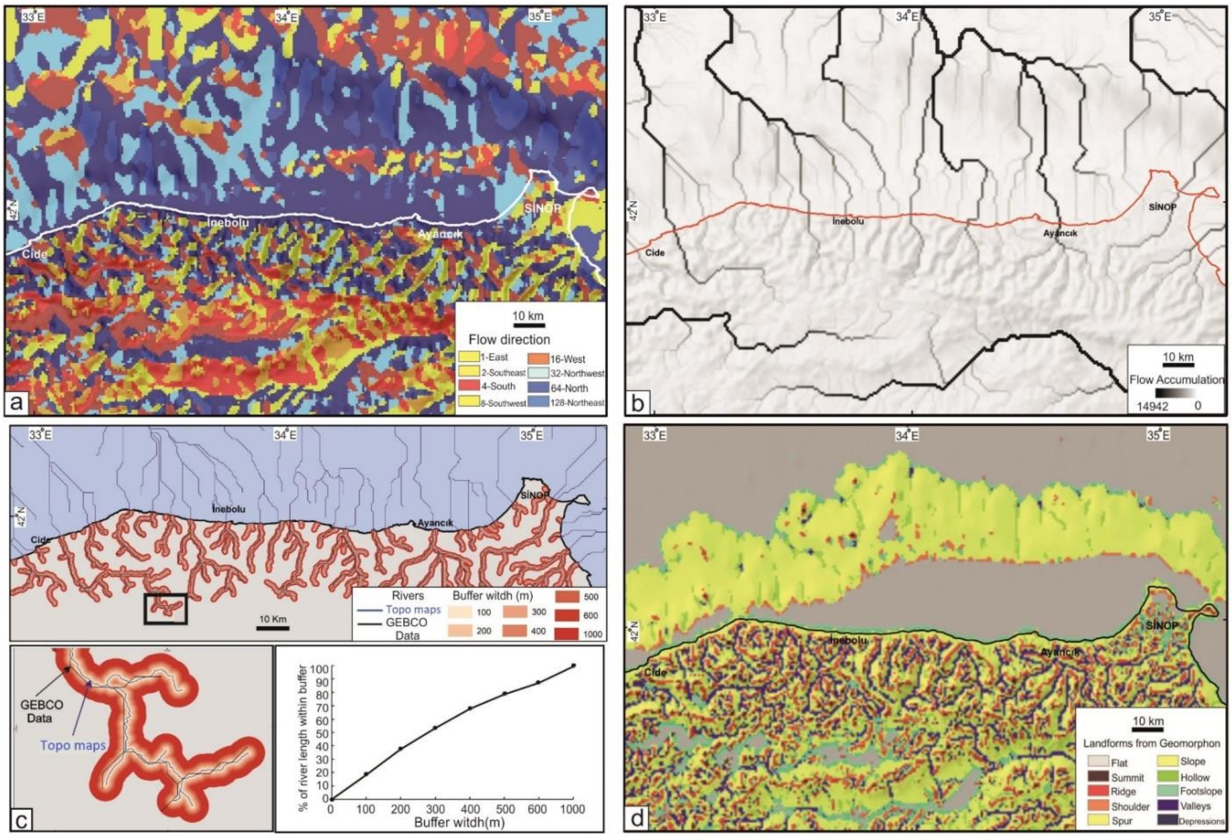

Fig. 3. Spatial layers produced from GEBCO DEM. (a) Flow direction; (b) Flow accumulation; (c) Comparison of DEMs streams with Buffer values; (d) Landforms.

The extracted GEBCO land rivers were compared to 1/25K topo map' rivers by using buffering method for accuracy assessment. The buffer polygons were applied to map' rivers, with 100, 200, 300, 400, 500 and 1000 meters. Buffers and GEBCO rivers were intersected and calculated the sum of lengths of rivers. (Fig 3c). The rivers were geometrically intersected with ratio of 75% between 0-400 meters. This ratio shows that the rivers on the land continue at sea in this area. Later, the landform data was produced by using Grass software plus Geomorphon script (Figure 3d). DEM derived other data from ArcGIS software were depth contours, maps of elevation/depth, slope and hillshade (Figs. 4 and 5). The canyons on the slope, the boundaries of the shelf break, the foot of slope were digitized as lines by the support of superimposed all data (Figs. 4a and 5c). The delineated canyon lines were visually controlled with the data of Harris et al. (2014) and Popescu et al. (2015). Lastly, a profile was delineated on the steep slope. For this profile, depth and slope values were calculated at every 200 m (Figure 5b).

A conventional data processing stream (Yılmaz 1987) was applied to the multichannel seismic reflection data by İşcan et al. (2019) under 'Echos' seismic data processing software as follows: data transcription, inline geometry definition, shot-receiver static correction, editing, shot muting, gain correction, Common Depth Point (CDP) sorting, velocity analysis, Normal Move Out (NMO) correction, muting, stacking, predictive deconvolution, band-pass filtering, finite difference time migration, and automatic gain correction. Five seismic sections with 3.0 sec recording time simply indicate the subsurface up to a few kilometers deep (Figs. 5c and 6).

Results and Discussion

Drainage network, seismic stratigraphy and shelf paleochannels

In this study, the total drainage network with the length of 2238 km was calculated offshore Cide-Sinop by using GIS software tools and the gridded elevation and bathymetry data from GEBCO-2014. This drainage network consists of a submarine channel network (1548 km length) and a land river network (690 km length). The flow occurs with the rates of 70% and 30% on the seafloor and on the land respectively. The obtained pattern of the offshore channels is comparable to that onland. Approximately, thirty submarine channels appeared at the continuation of the land rivers. Contributories up to the order of six were detected in the study area (Figs. 3 and 4a). This network indicates that the rivers continue to flow beyond the landfall point into the shelf plain, slope, and abyssal plain. A dendritic drainage system where the river channels follow the slope of the terrain and form in V-shaped valleys, was observed. The channels converge toward the abyssal plain flowing northwards into deep waters (Figs. 3 and 4a).

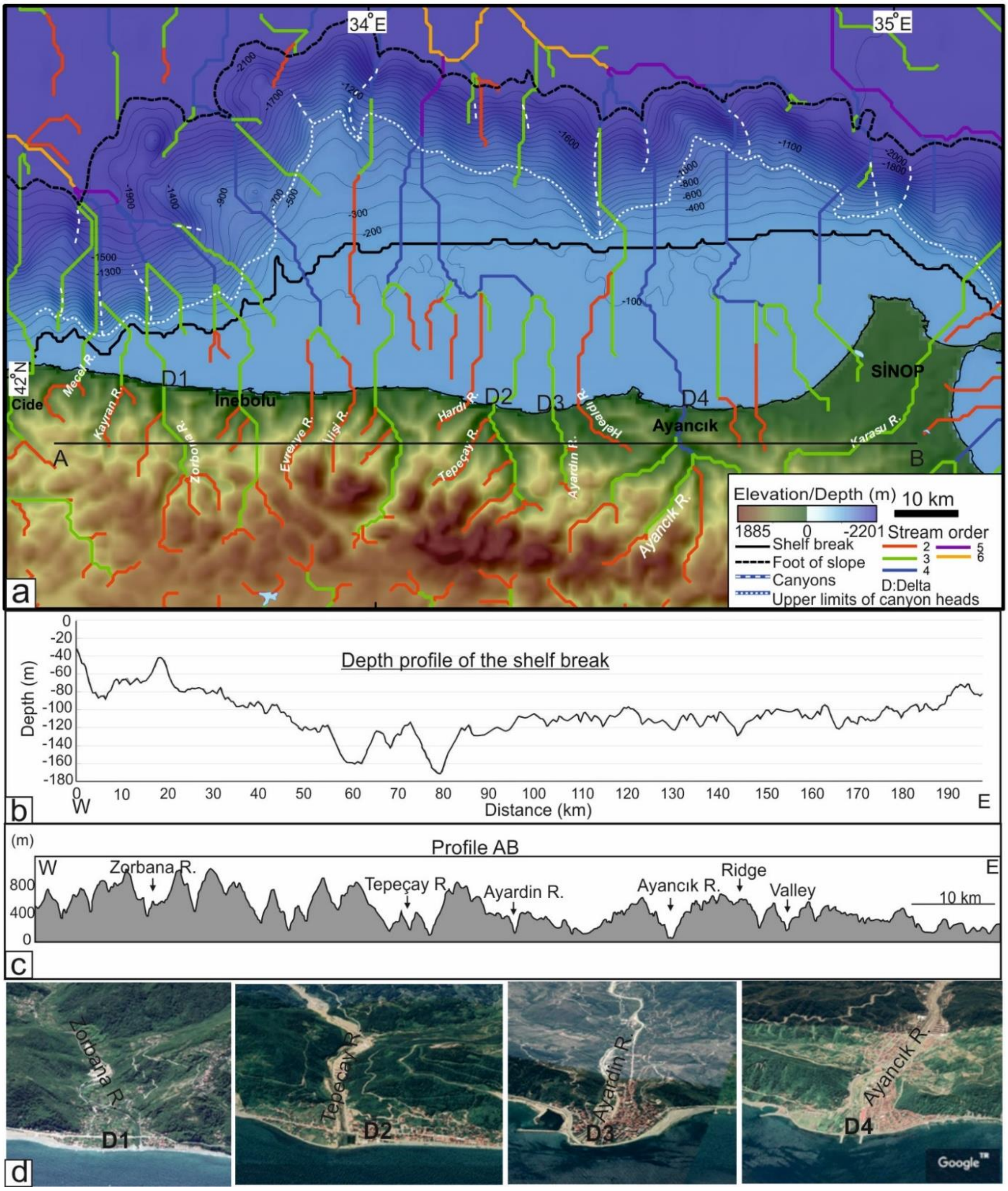

Fig 4. (a) Rivers, submarine contours and channels, shelf break, foot of the slope, canyons. (b) Depth profile of the shelf break. (c) Topographic profile of the study area. (d) The images of the major deltas on the google earth map.

Submarine channels drain a very narrow continental shelf (~5-10 km width) between Cide-İnebolu and offshore Sinop Peninsula, whilst, they drain a larger shelf zone from İnebolu toward to the west of Sinop Peninsula (~20-30 km width). From the inner shelf to shelf break, the shelf is generally smooth and flat and it is represented by ~100 m water depth (Figs. 3-5). The maximum slope of the shelf plain is 1° (Fig 5a). The water depth at the shelf break increases from -80 m to -120 m between Cide-İnebolu marine zone and it varies between -100 m and -130 m from offshore İnebolu to the Sinop Peninsula (Figure 4a and 4b). The shelf break is followed by shelf slope varying with the slope angles from 5° to 17°. The slope angle dramatically increases in the narrow shelf zone (between Cide-İnebolu and offshore Sinop Peninsula), whereas it gradually increases in the relatively larger shelf zone (between İnebolu and Sinop Peninsula) (Figure 5a). The slope face is dissected by several submarine canyons (Figs. 4 and 5). The canyons indent the shelf for ~5-10 km and follow from NW-SE to N-S orientations. The longest canyon (~20 km length) was observed offshore Ayancık. The upper limits of canyon heads locate close to shelf break in the narrow shelf zone (at ~ 150-200 m depth), whereas these limits locate deeper between İnebolu-Ayancık marine zone (from 200 m to 1100 m depth). The foot of the slope is delineated by approximately -2200 m depth contour. At this level, the shelf slope reaches the abyssal plain (Figs. 4 and 5).

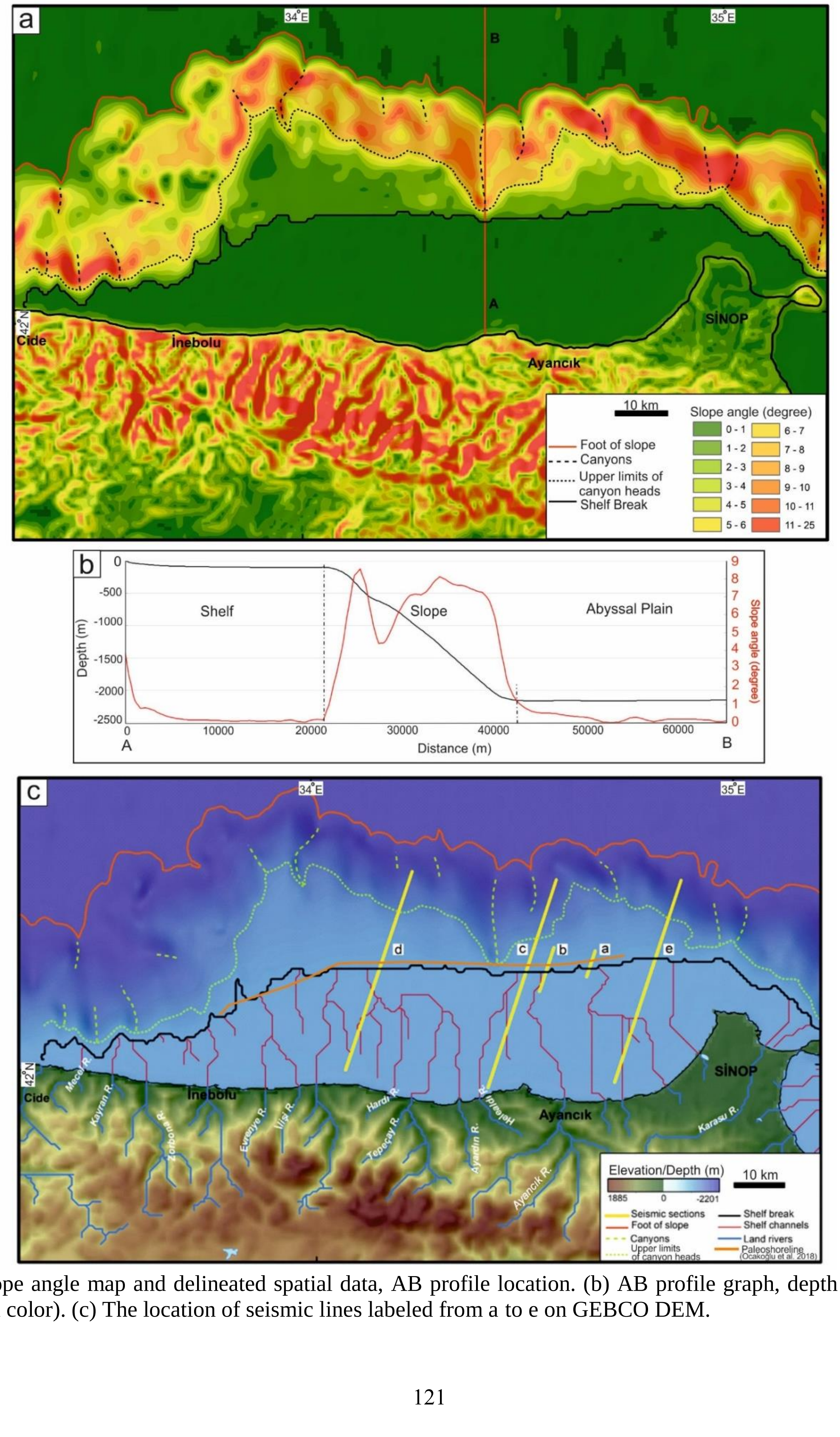

Fig. 5. (a) Slope angle map and delineated spatial data, AB profile location. (b) AB profile graph, depth (black color) and slope (red color). (c) The location of seismic lines labeled from a to e on GEBCO DEM.

The submarine channels drain a flat seafloor on the inner shelf. However, the morphology dramatically changes when they across the landfall point (Figs. 3-5). While, the topography is high around Çatalzeytin and İnebolu coast, with the average elevation of >800 m, it significantly decreases to approximately 500 m at Ayancık coast and less than 300 m in the Sinop Peninsula (Figure 4). From coast to the hinterland, the elevations rise to ~ 1800 m and the overall slope angles increase to 25° (Figure 5a). This topography was drained by small-scale rivers named as Karasu, Ayancık, Helardı, Ayardin, Tepeçay, Hardı, İlişi, Evrenye, Zorbona, Kayran and Mecel rivers from east to west. They flow from south to north draining the Pontides and form V-shaped valleys (Figs. 3-4). The deltas of these short rivers are not well developed and do not display a wide lobe at their mouths (Figure 4d). One of the major of these rivers, the Karasu River is born from the Pontides. It is 80 km long and passes through wide plains of Sinop Peninsula and flows into the shelf at Sinop Promontory. The strong wind and wave erosion do not let the development of its delta. At the west of Sinop Peninsula, the Ayancık River flows into the shelf offshore Ayancık. It is formed by the merging of many small rivers born from Pontides. The length of the river is 124 km. toward the west of Ayancık, three other rivers as Ayardin, Tepeçay and Zorbona rivers with the length of 19 km, 65 km and 61 km respectively flow into the shelf area. These rivers have only deltas with ~1-2 km wide. Toward the west of the Zorbona River where the shelf narrows, the rivers cannot develop their deltas (i.e. Mecel River, Figure 4).

To understand the contribution of these rivers to sedimentation across the shelf related with the derived submarine network in this study, we focused on the seismic stratigraphy of the upper sediments given by previous studies (Ocakoğlu et al. 2018, İşcan et al. 2019). We considered five seismic sections labeled from a to d that coincide with the submarine channels on the shelf area as much as possible (Figure 5c). Four main seismic units deposited on the shelf from the Upper Cretaceous–Paleocene to Plio-Pleistocene and named from shallow to deep as U1, U2, U3, and U4 by recent studies (Figure 6, Ocakoğlu et al. 2018; İşcan et al. 2019). The deposits from the Eocene to recent time (units 3, 2 and 1) are highly eroded from their upper surfaces and widely outcropped at the seafloor constituting a flat shelf plain across the study area. There are no significant recent deposits (Holocene deposits) observed in the study area. A few milliseconds above the erosional surface refers to a possible very thin sediment package (approximately 15 meters thick with the mean P wave velocity of 1600 m/sec; Figure 6a, 6b). This observation is consistent with the previous studies in the southern Black Sea shelf. Özhan (1989) interpreted approximately 15 m thick Holocene deposits on the high-resolution seismic data offshore Sinop Peninsula. Duman et al. (2006) defined a very thin veneer of transgressive sediments as recent delta deposits in the Cide-Sinop shelf area by sediment samples. They suggested that the sediments may have been stored across the shelf during the post-glacial sea level rise (Holocene) considering the study of Algan et al. (2002) in the Sakarya Delta. Moreover, Ryan et al. (1997a and 1997b) and Algan et al. (2002) indicated that this thin blanket deposits without onlapping character sit upon an erosional surface and support the fast sea level rise during the last transgression (Holocene).

This result reveals that the sediment loading potential of the small scale onland rivers is not high enough to flow through the whole shelf up to the abyssal plain at present and the derived submarine network in this study does not present the current lines of submarine channels. To question the development of this network in the past, we considered shelf break seismic stratigraphy that coincides with some branches of marine network (Figure 5c and Figure 6). This correlation indicates that the prograded delta deposits (U1) eroded by its top are only existed around the shelf break (Ocakoğlu et al. 2018; İşcan et al. 2019). The absence of a noticeable recent sedimentation above U1 and the existence of an erosional surface at the top of this unit indicate that the area was a terrestrial landscape until very recent time and the local delta deposits (U1) around the shelf break should correspond to last low stand time deposits. Thus, the derived marine network in this study should represent the last low stand time drainage system, the paleochannel network of the shelf area. This result supports the interpretation of Ocakoğlu et al. (2018) who mapped a paleoshoreline approximately represented by the shelf break in the study area.

In this scenario, during the Plio-Pleistocene time when the area was terrestrial, these onland rivers should prograde and reach the coast (Paleoshoreline) on the shelf. At that time, these rivers should have high energy with a stream power to induce lateral migration and to develop a dendritic drainage pattern on the shelf (Figs. 4 and 5). Similar, prograded delta deposits were also mapped at the shelf edge in Romania and Bulgaria, by Lericolais et al. (2011) and dated to the LGM (during Pleistocene). However, the strong evidences of erosion on the shelf were recognized on the seismic data because of the subaerial exposure of the shelf during this lowstand time (Figure 6). This intense erosion should have continued until the late Pleistocene that it probably erased most of the evidence of this ancient drainage network before the rapid submergence except the delta deposits which were only observed around the shelf break. The absence of any buried channel and channel fill deposits below the erosional surface on the seismic data from the shelf edge towards the interior support this idea (Figure 6). This interpretation is very compatible with Ocakoğlu et al. (2018) study who could not observe any evidence of such submarine network on the multibeam bathymetric data. They only marked some possible small channels over short distances toward outer shelf that probably developed by modern time marine environmental processes such as submarine currents. Similar observations were made by previous seismic studies in the other locations of the southern Black Sea shelf (Demirbağ et al. 1999; Algan et al. 2002; İşcan et al. 2019). However, offshore Romania in the northwestern Black Sea shelf, there were some buried channels observed (Lericolais et al. 2007; Popescu 2008; Lericolais et al. 2011).

Submarine canyon analysis

To understand the development of canyons during the last lowstand time and today, we focused on the canyon located close to shelf break offshore Ayancık River which is the major river of the study area (Figure 5c and Figure 6a). The head of the selected canyon is also situated very close to paleoshoreline. The depth profile along the AB line and the seismic section c (Figure 5 and Figure 6c) crossing the wall of this canyon indicate that the bathymetry decreases to ~ -2100 m through the canyon. The inclination angle of the canyon wall starts with 4° at the beginning of shelf-slope then it increases to 9° towards to abyssal plain (Figure 5a). This symmetrical canyon lies from south to north with a total of 20 km long. The seismic section c indicates that the wall of the canyon has no recent sediment deposition except some sliding materials (Figure 6c). Thus, this canyon should not be active at present. Instead, this canyon and the other canyons located close to shelf break (paleoshoreline, Figure 5c) should be active during the last sea level lowstand time.

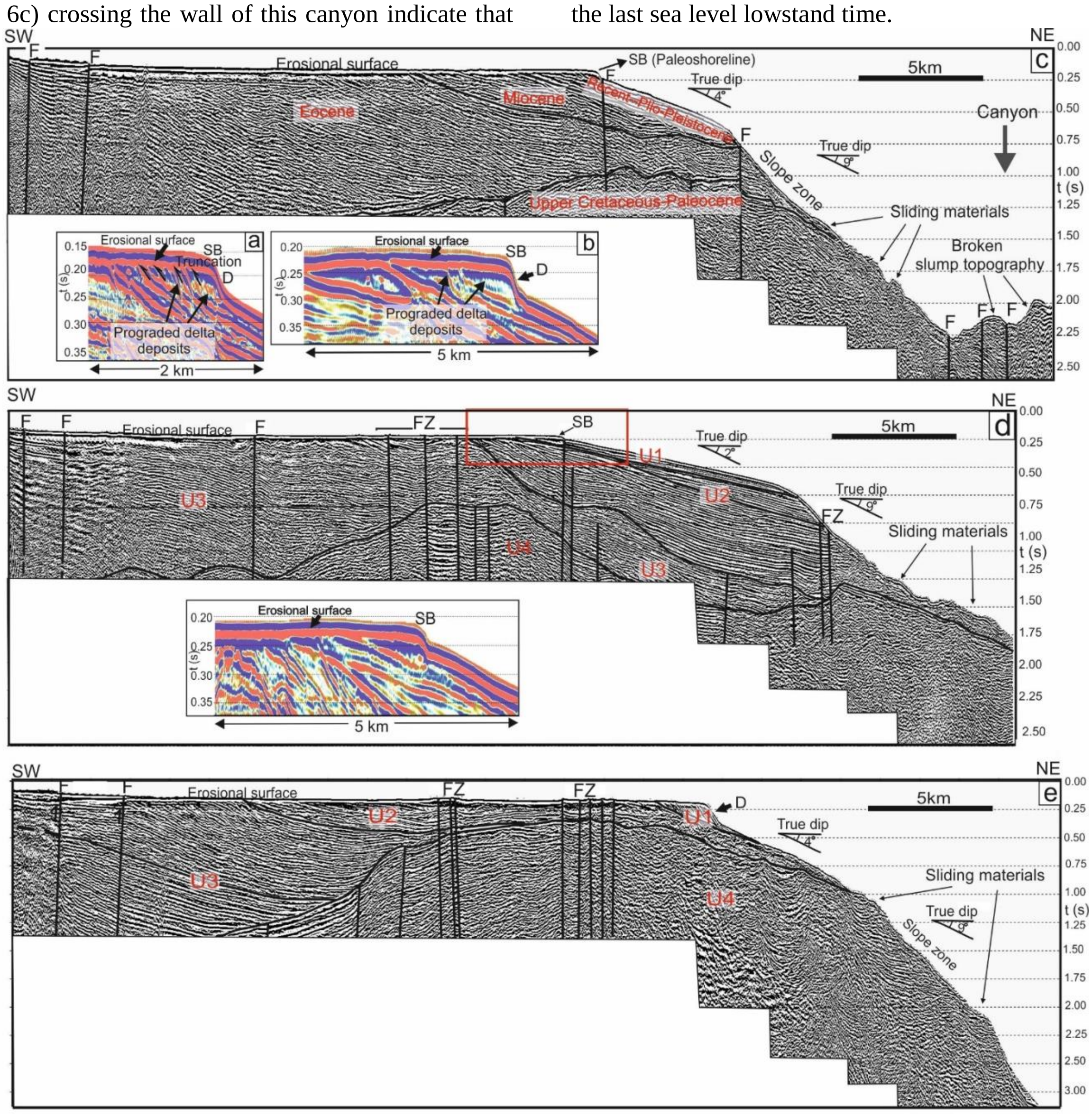

Fig. 6. The seismic sections a, b, c, d and e (modified from Ocakoğlu et al. 2018 and İşcan et al. 2019). D: Delta, SB: shelf break, F: fault, FZ: Fault zone. The vertical exaggeration is ~5.

The limited extension of prograted delta deposits which were coincided with the channels of paleomarine network around the shelf break (paleoshoreline), supports this idea (Figure 5c, Figure 6). On the other hand, the canyons located far from the shelf break (paleoshoreline) from -500 m to -1000 m between offshore Cide-Sinop should be younger than the canyons located close to paleoshoreline (Figure 4a). Because we know that the Black Sea has never dropped to these levels. Instead, their origin should be younger and they should develop during the highstand period of the Black Sea. Thus, these canyons are also not active today. Recent studies indicated that these canyons are influenced by submarine erosion and active tectonic at present (Ocakoğlu et al. 2018; İşcan et al. 2019). The active strike-slip faults at the shelf break and slope should cause gravitational instability and generate mass movements along the canyon walls (Figure 6). Similarly, fault-controlled canyons are observed offshore Sakarya Delta by Algan et al. (2002). Yıldırım et al. (2013) also obtained fault-controlled coastal uplift rates (21 ± 7 m and 67 ± 1.4 m) along the onshore marine terraces near Ayancık during inter-glacial periods. These observations indicate that the canyons located offshore İnebolu-Sinop do not belong to canyon category classified as active canyons at present by Popescu et al. (2015) for southern Black Sea shelf. However, we do not have any idea about the recent activity of canyons located at the narrow shelf offshore Cide-İnebolu and offshore Sinop Peninsula (Figure 4a and Figure 5c). These canyons may be active in both lowstand and highstand conditions as mentioned by Jipa and Panin (2020) for the canyons of southern Black Sea shelf. Further seismic studies are required within this narrow zone in order to investigate these morphological features intensively.

Conclusions

The GEBCO-2014 seamless data which is a combination of land elevation and bathymetry were processed to generate onland rivers, submarine channels, depth contours and slope by using GIS software tools. The shelf break, the foot of the slope, and the canyons on the slope were delineated as new spatial data by superimposing all of the data for the offshore Cide-Sinop in the Southern Black Sea. The derived drainage network with the total of 2238 km length indicates that there is a dendritic drainage pattern with the flow direction from south to the north extending from land to shelf plain, shelf break and converging toward the abyssal plain in the study area. The flow direction was extracted with the rates of 70% and 30% on the seafloor and on the land respectively. While the derived onland rivers are 75% compatible with the rivers of 1/25K topo maps, the traces of marine rivers are not traceable on the seafloor. There are no any significant recent delta deposits observed on the shelf plain. The only some prograded delta deposits which they are truncated with an erosional surface by their top, outcrop only at the shelf break. The well correlation between these delta deposits and derived submarine network at the shelf break indicates that the derived marine network cannot represents the current drainage system on the shelf. Instead, it should represent the paleochannel network across the shelf and it should be active during the last lowstand time (at least in Late Pleistocene-Holocene). At that time, the canyons located at the shelf break should be also developed by this system. Then, before the Black Sea flooding, a strong erosion period must have affected the area until all traces of this marine network, without left any buried channel today, are removed. Seismic sections indicate that the canyons located across the shelf are not active today. Instead, they are under the influence of submarine erosion and active tectonic at present.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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