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Mapping onland river channels up to the seafloor along the west coast of India

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A river channel terminates at the sea in the form of a delta. Recent research has reported the existence of marine channels and depositional environments. This has been further corroborated by the significant discoveries of oil and gas in deepwater. Such studies have raised several questions like: How do these channels originate deep in the ocean floor? Are these channels extensions of present-day onland river systems? The present communication presents a GIS-based analytical study of bathymetry and elevation to establish the relation between present-day onland river systems and marine channel systems in the offshore west coast of India.

Keywords: River channels, mapping, seafloor, oil and gas.

A RIVER originates from the hills, flows through the plains and terminates at the sea. Significant channel sand

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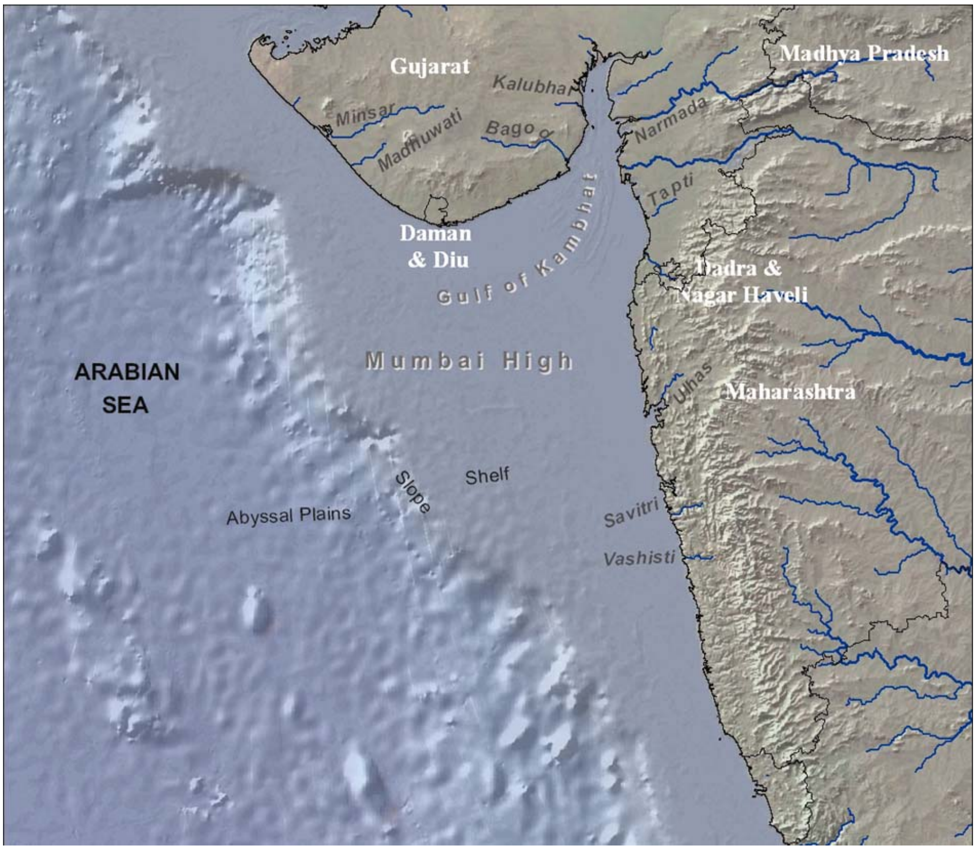

Figure 1. General Bathymetric Chart of the Oceans data and features of the study area.

formations in deepwater region of Krishna–Godavari basin in the offshore east coast of India understate that river channel systems exist beyond land into the sea[1]. This has led to a paradigm change in our understanding of a river system, substantiated through the discovery of submarine river channels that carry sediments and provide a good depositional environment for conventional energy resources. Advances over the past two decades in the development of geospatial tools for processing bathymetry have enabled the observation that has revolutionized our understanding of deepwater systems and processes[2]. Significant hydrocarbon reserves have been discovered in the Tertiary, deep-marine clastic reservoirs off the coasts of six of the world's continents. Estimates (as of 2002) are upward of 58 billion BOE in deepwater reservoirs, with less than 5% of discoveries having been exploited[3].

Unlike onland slope-channel systems, the literature on submarine channel systems is limited. Clark *et al.*[4] published a comprehensive study of modern submarine-fan morphologies and lithology worldwide, concluding that the geometry of a fan is dominantly influenced by the geometry of the receiving basin. Most work is based on seismic attributes of the submarine litho-column recorded from a seismic survey. Seismic data have the added advantage of subsurface penetration; however the resolution is poor compared to surface bathymetric surveys utilized for present-day channel studies.

The study area (Figure 1) is located in the seafloor of the western coast of India off Mumbai High, spanning both the continental slope and deep-basin geomorphic provinces, up to a depth of about 4000 m. Several onland river systems drain to this coast. The shelf expands for about 300 km from the coast followed by a short slope (30–40 km) to the west. The abyssal plain spans from a depth of 2400 m from the slope and terminates at the mid oceanic ridge between the Indian and African plates. Seafloor slopes range from 0° to 26°, the higher values conforming to the slope region. The shelf and abyssal plains show large-scale mounds and topographic features with a predominant NW–SE orientation.

General Bathymetric Chart of the Oceans (GEBCO) provides global bathymetry gridded datasets for the world's oceans in 30 arc sec (roughly 1 km at the equator) and 1 min grids available for download from British Oceanographic Data Centre (BODC; http://www.bodc.ac.uk). The bathymetry for the region was obtained. The resolution of the data was found to be ideal for detection of submarine channels which are of a larger dimension compared to onland river systems (Figure 1). Alternative sources like multibeam surveys and seismic-derived bathymetry were found to be both costly and limited in terms of spatial extent for the study scale. The gridded bathymetry data from GEBCO was available in a digital elevation model (DEM) which was compatible for processing, analysis and interpretation within a geographical information system (GIS).

The GEBCO DEM was processed for its derivatives in a GIS and spatially correlated with onland mapping of major rivers. GIS provides several algorithms and tools to process topographic features from elevation and bathymetric models, including hydrological analysis. GIS provides faster data processing and automated derivation of hydrological features using a DEM. A workflow model (Figure 2) for the processes was defined for extraction of marine channels from bathymetric data. The channels were ordered according to Strahler[5], to establish confluence of tributaries from the continental slope region towards the deep ocean. The results were overlain with land data where onland rivers derived from SRTM DEM were displayed along with the automatically derived channels for visual interpretation.

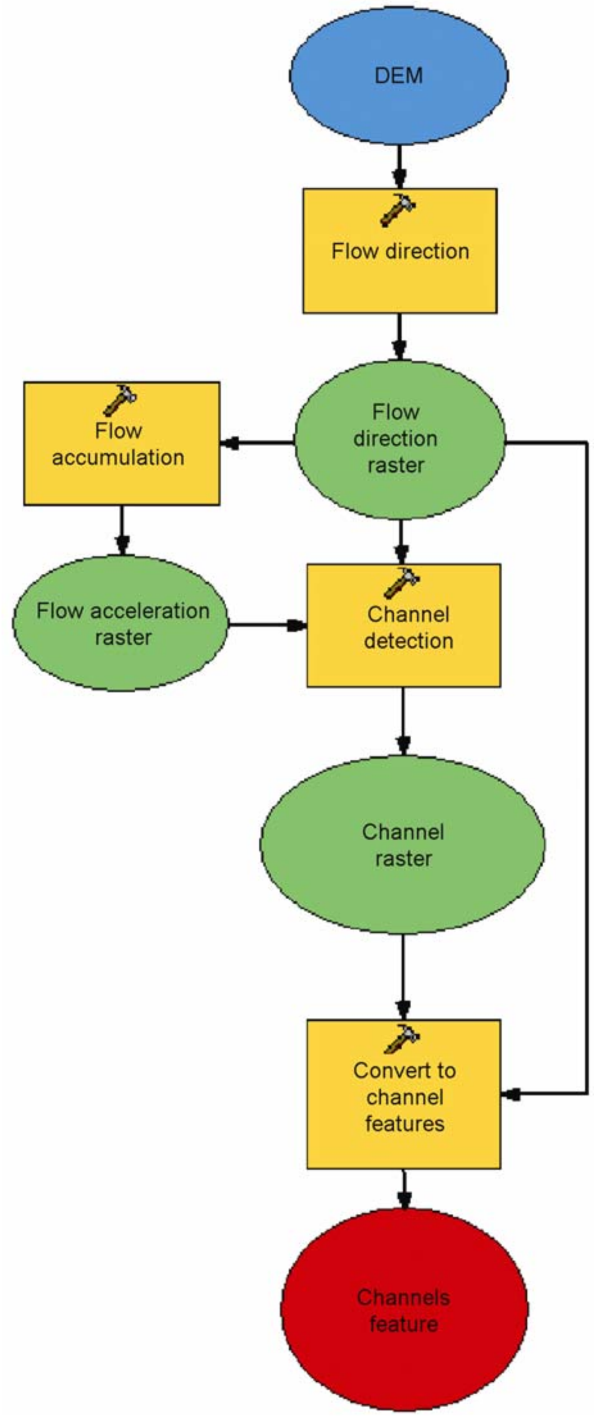

Figure 2. The processing workflow.

The bathymetric profile of the region depicts physiographic divisions and their relative elevation (Figure 3). The shelf varies from about 20 km to over 200 km owing to the rich sediment transport through the Gulf of Kambhat. The shelf is a relatively flat region compared to the abyssal plains where some seamounts of varying scale are observed (Figure 1). The slope region shows some deep trenches and gullies, which indicate turbid sediment flow and scouring.

The pattern of the offshore channels obtained is comparable to that onland. Contributories up to the order of five were detected on the seafloor, most of which originated from the coast, continuing from where the onland rivers terminated. This provides a strong correlation to the fact that rivers continue to flow beyond the landfall point into the deep seas, as established by previous research through seismic geomorphology[6]. Rivers in the Western Ghats (Figure 3) like Narmada, Tapti, Ulhas, Savitri, etc. extend into the shelf and converge before the slope. Similarly, the rivers in Saurashtra, Gujarat like Minsar, Madhumati, etc. conflux and converge in the abyssal plains. Rivers draining to the east of Gulf of Kambhat, like Bagod, Kalubhar, etc. show strong extensions into the sea as well. Further, in the abyssal plains, we see the confluence of all the channels from Saurashtra and the Western Ghats. This confluence flows further towards the equator along the Kerala–Konkan deepwater system (Figure 3).

These observations provide a strong evidence of existence of marine channels and their extensions to onland river systems. This demonstrates that sediments from the land are transported beyond deltas to the deep ocean enabling suitable deposition and accumulation resulting in biogenic hydrocarbon sources in clastic sand formations. This is a positive corroboration of recent research[7]. The confluence of channels in the abyssal plains flowing southwards into deepwater Kerala–Konkan indicates the possibility of a larger depositional basin to the south. This calls for detailed studies which possibly could lead to further oil and gas discoveries in future. Such regional studies should lead to detailed research with higher resolution data from multiple sources to detect intricate channel systems in local scale and sufficed by seismic geomorphologic studies to establish palaeo-channels,

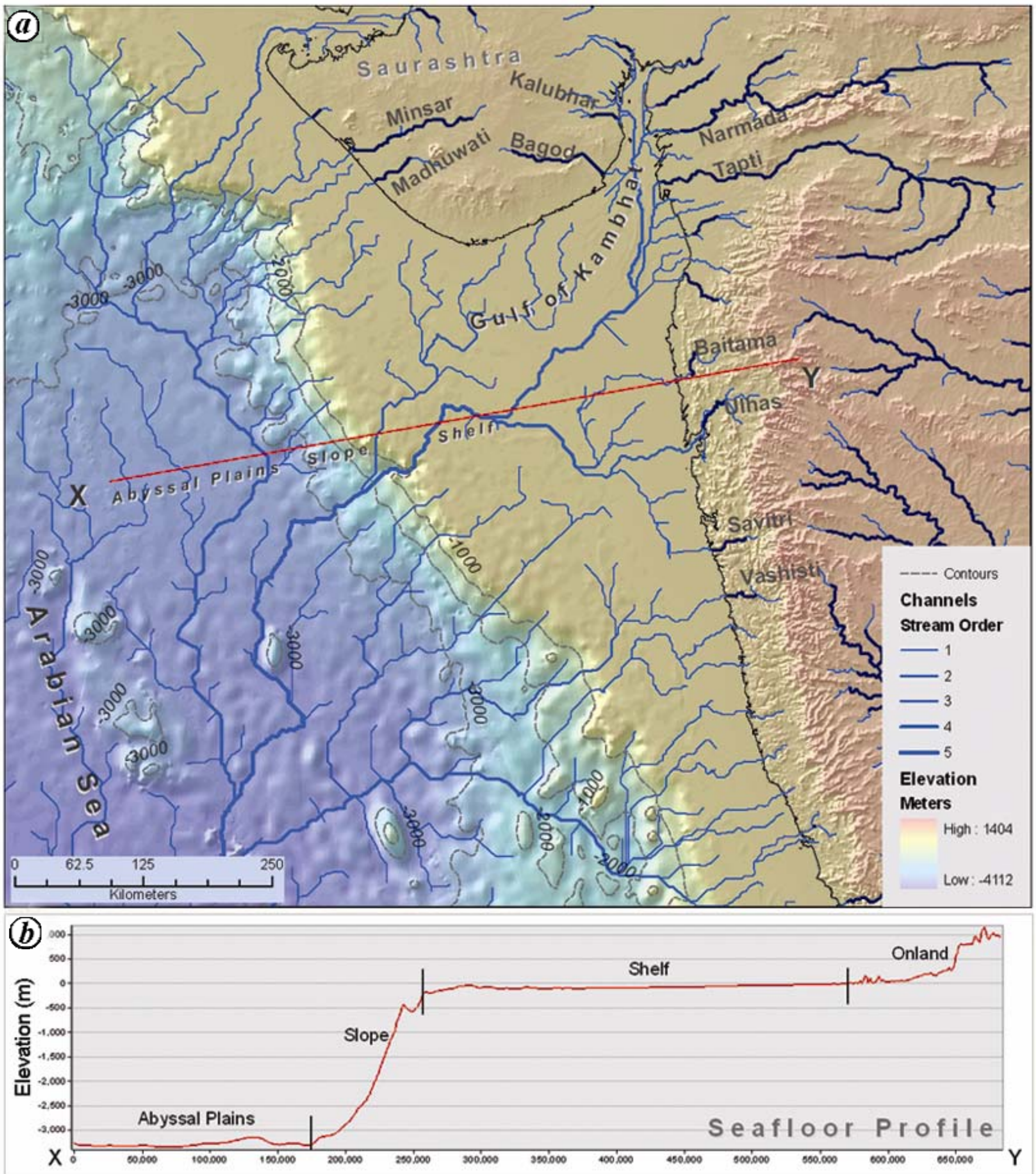

Figure 3. ***a***, Mapping of digital elevation model-derived seafloor channels and onland rivers. ***b***, Seafloor profile along section *X–Y*.

sediment migration and geological reconstruction of deepwater depositional systems.

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