to explain that earth degassing is behind the creation of a localized greenhouse effect. As this earthquake was caused by thrust faulting accompanying convergent tectonism, considerable emissions might have occurred along the foothills through the relatively porous and faulted media. From both the pre- and post-NOAA images, it can be deciphered that there are noticeable changes in the thermal regime along the MFT. On the NOAA thermal images, the thermal line is observed during the stress periods and disappears after the release of stress. Thus, it appears that changes in the thermal regime can be more extensively used to understand impending earthquakes.

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Delineation of buried channels of Bharathappuzha by single-channel shallow seismic survey

Single-channel marine seismic surveys can identify the basic features of buried river channels. Since the methods deal basically with the subsurface acoustic reflectors, their termination, configuration, trend and dimension; any kind of incision changes the nature of the entire geometry. Palaeo channels are identified based on the analysis and interpretation of seismic data, according to the general concepts established in the field of seismic stratigraphy[1,2]. Generally, trunk/main channels have box-like, symmetric cross-sections, whereas smaller tributary channels have more V-shaped or asymmetric cross-sections[3].

Bharathappuzha is the second longest river in Kerala, with a length of 209 km. The head waters of the main tributary of Bharathappuzha originate in the Anaimalai Hills, Western Ghats and flow westwards through Palakkad Gap and empty into the Arabian Sea at Ponnani. Biyyam Kayal is considered as the earlier mouth of Bharathappuzha, which enters into the Arabian Sea at Munambam, 8 km south of the present-day river mouth. Sea-level rise during the Holocene transgression has affected the

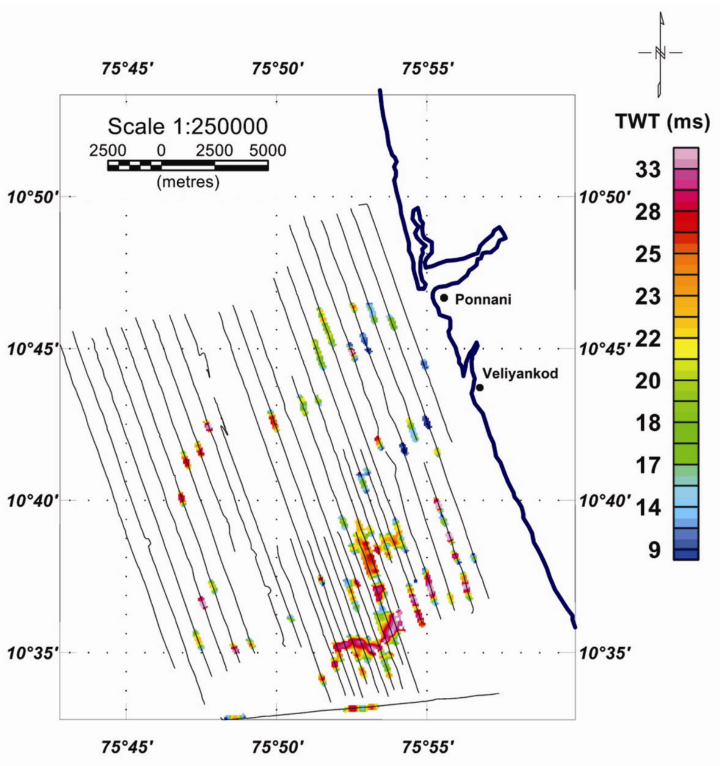

Figure 1. Two-way-travel (ms) of buried channel along with the cruise track off Bharathappuzha River, Kerala coast, India.

Kerala coast and must have submerged the channels of Bharathappuzha under the sea[4]. A coast-parallel line (single channel) acquired earlier by the Geological Survey of India (GSI) has indicated the signatures of river channels in the offshore areas of Bharathappuzha River mouth. A detailed close interval seismic survey was planned to delineate the submerged channels of Bharathappuzha and to understand the nature of the sediments in them. Hence, the cruise SD-241 was carried out on-board GSI research vessel *R. V. Samudra Shaudhikama.*

Shallow seismic survey was carried out along 31 coast-parallel and 3 coast-perpendicular lines between water depths of 8 and 38 m; the line spacing varied from 500 to 1000 m. The maximum length of the lines was up to 20 km. The survey was carried out at a ship speed of 5 knots/h in order to acquire good-quality data. Survey equipment includes a combination of SIG2 MILLE energy source unit (IXSEA, French-make) with sparker tow cable fitted with a multi electrode array (ELC1200) having 25 nos of electrodes and a compatible streamer-receiving unit connected through preamplifier to an acquisition and processing unit. The acquisition and processing unit in turn is connected to a computer for visual graphic display of acquired seismic data with controls over acquisition and data-logging parameters like firing rate, sweeping rate, format of digital data (SEGY Float IEEE), length of digital seismic record and several other parameters as displayed in the Delph seismic acquisition software. The digital seismic data are processed using the Delph seismic interpretation software which has the facility to apply different modes of filters, remove multiples and water column, gain controls and digitizing seismic interfaces. Both the acquisition and interpretation software installed in the computer are made operational through two removable dongle keys fitted to the processing unit. The navigation and position fixing during the entire survey operation is monitored by a Leica (model no. CR-1000, Swiss-make) and DGPS Beacon receivers installed on-board *R. V. Samudra Shaudhikama*. During seismic data acquisition, the electrode array (ELC1200) of the seismic system received and fired energy from SIG2MILLE source at a rate of 160/250 J/1000 ms. The survey was carried out with digital recording of positions/distances along a transect (*X*-axis; positions obtained by DGPS fed to seismic data acquisition processor) and corresponding two-way travel time (ms) across seismic interfaces (*Y*-axis) on real-time basis. The recorded signals were visible as seismograms on the computer screen, which was controlled through various modules of the Delph seismic software. The digital seismic records were subjected to appropriate processing like filtering, multiple removal, signature deconvolution, gain control, heave correction, stacking, water column removal, etc. and seismic reflectors were tracked, digitized and represented as two-way-travel (TWT) sections. The time sections of different profiles were plotted using GRAPHER IV software and the TWT map of the channels was prepared using GEOSOFT ver. 8. All the standard methods in the buried channel identification like pattern of the channel

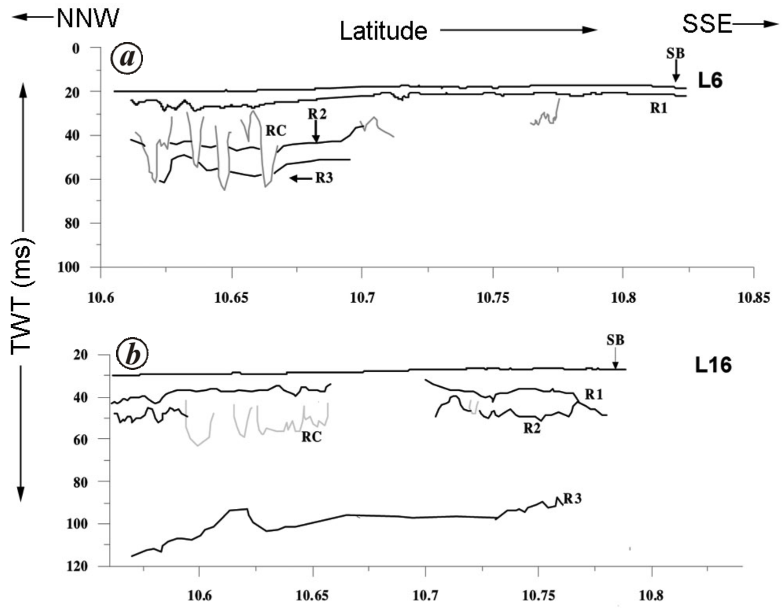

Figure 2. Representative profiles depicting buried channels cutting across reflectors.

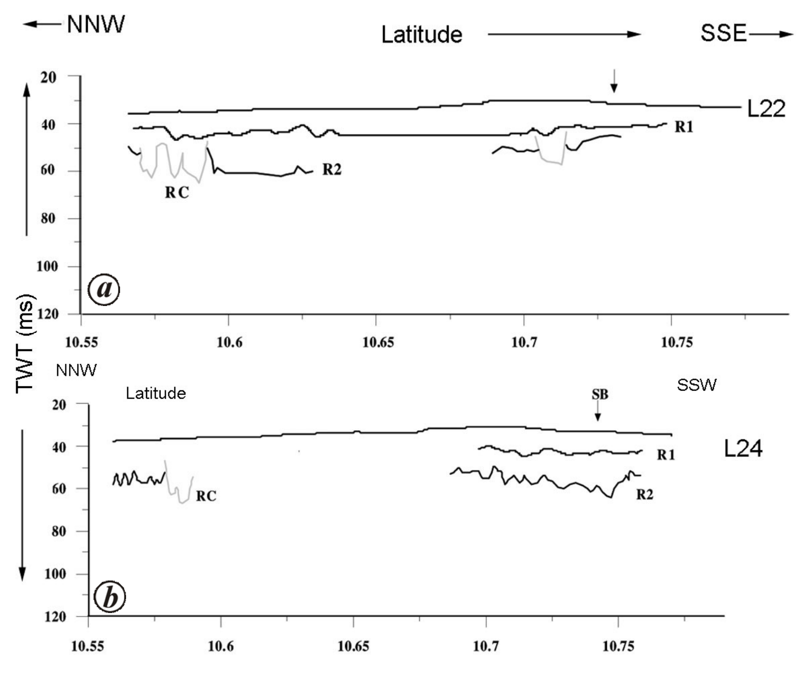

Figure 3. Representative profiles depicting the channel unification away from the shore.

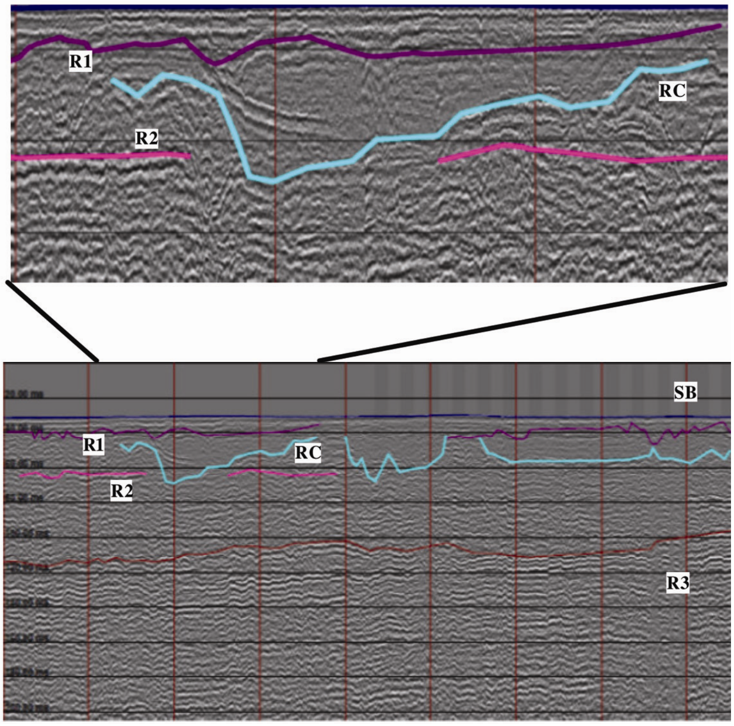

Figure 4. Representative seismogram of profile with the zoom portion of the channel.

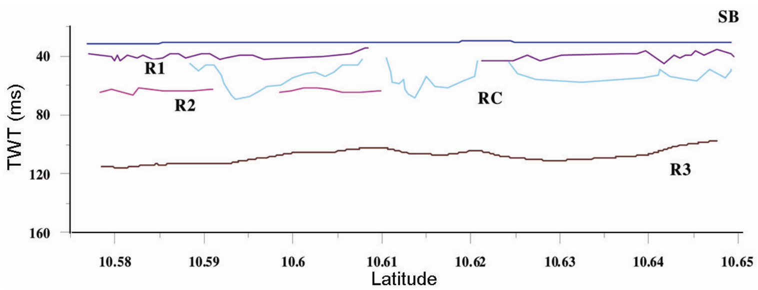

Figure 5. Asymmetric, V-shaped channels and small incision along the profile.

in the marine fluvial environment, reflection geometry, differential compaction, depth and width of the channels were employed while processing the data in order to prevent wrong interpretation.

Twenty-nine coast-parallel and two cross lines were processed in order to delineate the buried river channels (Figure 1). Bathymetric survey was also carried out along the seismic lines in order to understand the nature of the seafloor. The seafloor is gently dipping seaward without surface manifestation of any channels. Three reflectors, mainly R1, R2 and R3, were identified and the buried channels were marked as RC based on the vertical incisions in the seismic reflections (Figure 2 *a* and *b*). The buried channels were identified in most of the lines; they were prominent in the lines L6 and L8 and cut across the reflectors R2 and R3. The discontinuities in the reflection pattern in a particular region are considered as the indication of buried channels. The channels are mainly found below the reflector R1. Though the channels could be deciphered, the deeper reflectors were not identified in all the profiles. At some places, channel width is narrow and the extensions are not observed in the nearby profiles (Figure 2 *b*), may be due to the absence of the channel signatures. As we move away from the shore to the deep sea, channel unification is observed (Figure 3 *a* and *b*). From the cross lines, it is evident that channel depth is similar to that in the coast-parallel lines.

Seismogram of profiles shows that flanks of the channel are inclined which truncate the underlying strata (R2) and also indicate lateral accretion (Figure 4). Asymmetric and V-shaped channels are observed along with small incisions (Figure 5).

TWT (ms) of the buried channel appears to be blank where there is no trace of channels (Figure 6). The difference in time of the seabed and the channel varies from 9 ms near the coast to 33 ms in deep water. Since the channel incised the reflectors R1 and R2 at many places, attributing a uniform velocity between the seabed and the channels may not be accurate. However, approximate depths in different parts of the survey area can be deciphered. An average velocity of 1800 m/s will calculate the depth range of the channel from 8 to 29 m.

The channel distribution is delineated based on the location of incised channels identified in seismic records, and their depths, widths and continuity in the

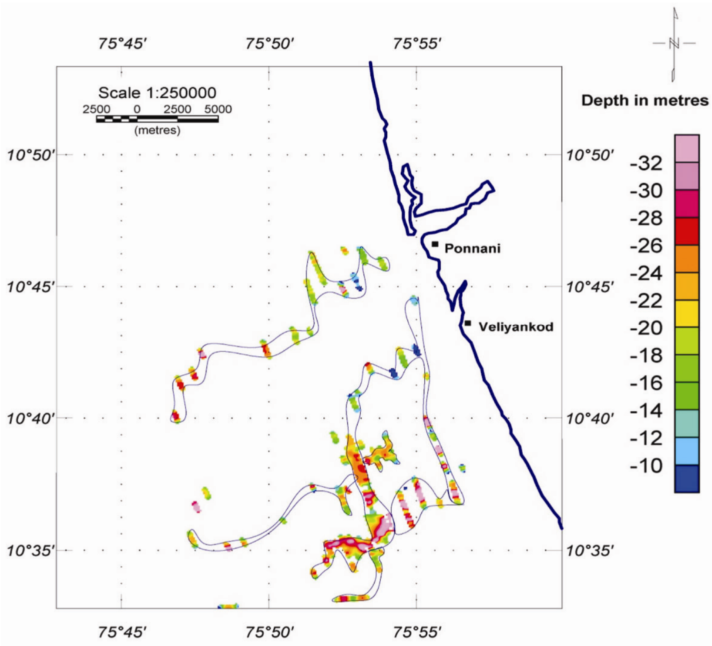

Figure 6. TWT map of buried channel off Bharathappuzha River, Kerala coast.

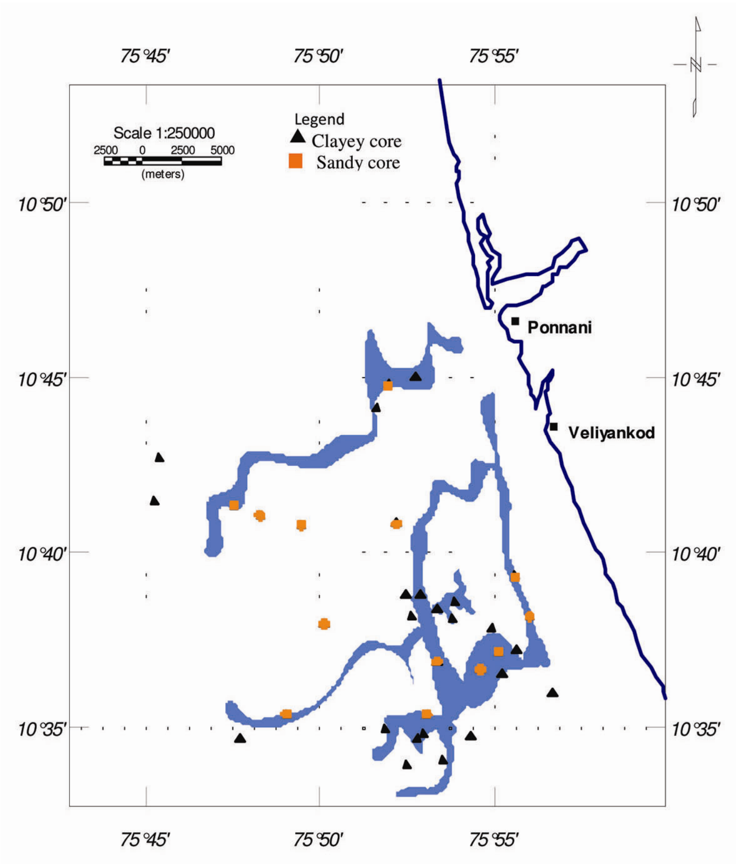

Figure 7. Interpreted buried channel with sample locations off Bharathappuzha River, Kerala coast.

contiguous seismic profiles (Figure 7). The main channel which extends from the present river mouth to the deep sea is clearly identified. An attempt has been made to locate the palaeo channels and their tributaries as well. In the southern part of the map, the main channel and its branching tributaries are marked. Presence of fluvial sand in the identified channel confirms that the features are the buried river channels.

From the seismic data it can be concluded that there are two sets of channels in the northern and the southern parts of the study area. The northern channel can be assumed as the extension of the present-day Bharathappuzha river, whereas the southern channel may be the palaeo-channel of Bharathappuzha which was debouching into the Arabian Sea at Munambam several years ago, before the shifting of the Bharathappuzha course to the north.

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