importance. However, unavailability of climatic data undermines the scope of thermally efficient planning. The proposed methodology uses the geographical coordinates and hour angle as necessary inputs to estimate the incoming extraterrestrial radiation. It therefore serves to establish the design parameters necessary for the thermal design of buildings in the absence of climatic data.

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A possible impact crater from Outer Continental Shelf off Cochin, Arabian Sea, India

During the Cruise SR-004, taken up in August 2014 by *RV Samudra Ratnakar* of the Geological Survey of India, high resolution sea bed survey by swath bathymetry and sub-bottom profiling were carried out in the outer continental shelf off the Cochin coast, 65 km SW of Cochin, an isolated large circular depression was observed in an otherwise gently sloping (0.8°) sea floor (Figure 1). Depth of the outer shelf in the eastern part of the depression is 155 m and 160 m on the western side. Part of a submarine channel has also been identified in the outer shelf and slope and indications of a few faults are seen in the vicinity of the shelf margin. These faults are about 60 to 70 km west of the coast occurring at depths varying from 100 to 350 m. One E–W trending fault is 2–2.5 km north of the depression. This isolated bowl-shaped depression with a diameter of about 600 m and a maximum depth of 40 m looks quite interesting owing to its size, shape and occurrence in isolation (Figures 2 and 3). Wall of the depression has a slope varying from 7° to 20°. The circular structure shows truncated cone shape in the cross section of sub-bottom profile. The slope of the upper walls of the structure is 5–7° and that of the lower parts of the wall in the cross section is 18–20° (Figure 4). The slope of the upper part is gentler in the north eastern half of the circular depression. The depression identified is the largest one ever reported from continental margin of India and seems unique. The isolated occurrence, large size and smooth disc

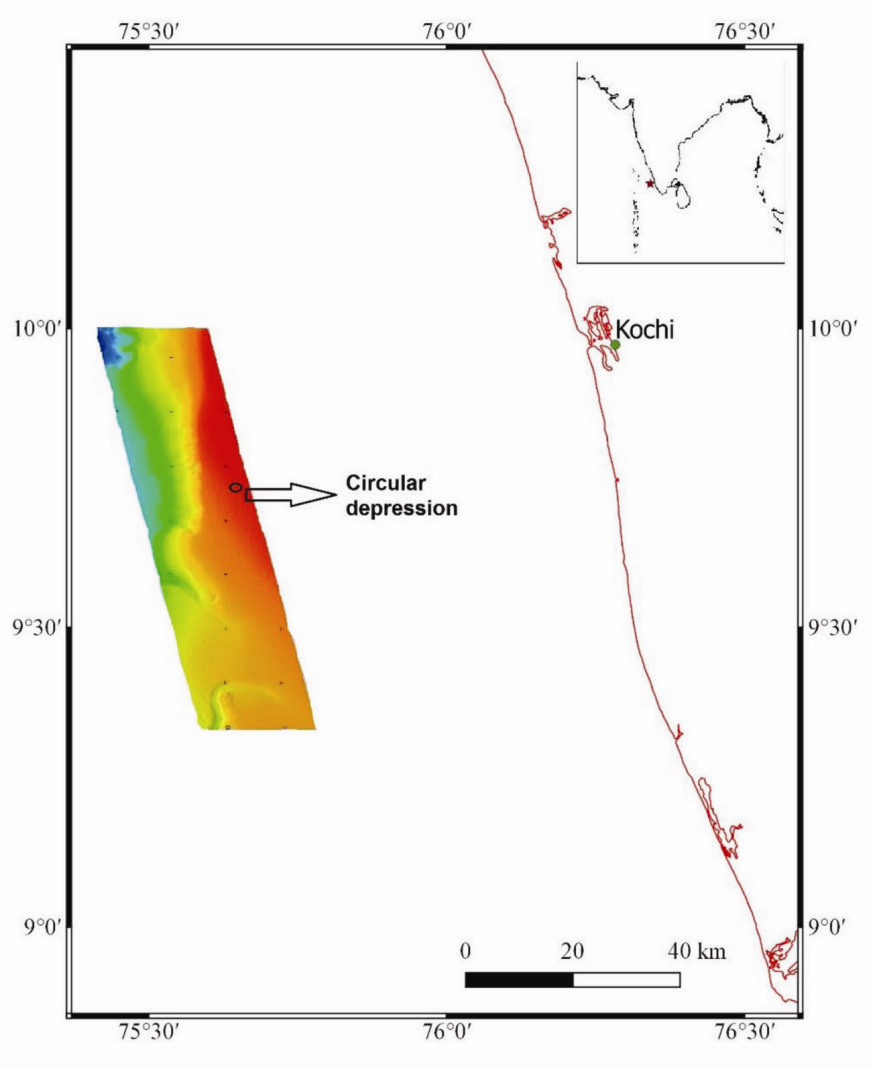

Figure 1. Location of circular depression within the survey area off the Cochin coast, Arabian Sea.

shape makes it different from those reported by earlier workers from Indian continental margin.

Circular depressions of varying sizes identified on the sea floor are ascribed to escape of gas formed due to biogenic decay of organic matter in the sediment, dissolution of carbonate rocks or to meteorite impact. Gas escape structures or pockmarks are craters formed in the seabed by the eruption and subsequent seepage of gas and pore fluids[1,2]. They are found to be ranging from a few meters to 100s of meters in diameter and a few meters to 10s of meters in depth. A series of pockmarks (total of 112) were reported from the western continental margin of India off Goa[3]. Active and relict type pockmarks have been noticed in the continental shelf and upper slope from Kundapur in Karnataka to Kasaragod in Kerala. In general, these pockmarks are 80–130 m in diameter and 0.75–2.5 m deep. They have been ascribed to biogenic gas escape from organic-rich sediments in the slope and thermogenic gas emanating from deep seated faults, fractures and lineaments[4]. Three pockmarks with depths 159, 79 and 53 m wide and 54, 24 and 15 m deep were reported from the outer continental shelf and slope off the Karwar coast[5]. Two circular pock marks are also identified from this zone.

The saucer-like shape and the isolated occurrence off the coast of Cochin reported in this work favour the possibility of it being an impact crater than a pockmark formed by the escape of biogenic gas. Further, the occurrence of carbonate rocks to the extent of generating large dissolution structures is not known from the area.

Meteorite impact craters occur as solitary structures. Nature of occurrence and morphology of the depression in the study area, suggest resemblance to a meteorite impact structure. Unlike the terrestrial impact structures which are susceptible to denudational processes, leading to alteration or obliteration of such structures, submarine structures maintain their shape until they get filled up by sediments.

Reported marine impact features are very few like Chesapeake Bay in the United States and Molner impact structure off Norway[6,7]. Both are geologically very old (Late Eocene and Late Jurassic). Chatterjee *et al.*[8] have hypothesized the Shiva crater as a 500 km diameter impact structure off Maharashtra Coast. This

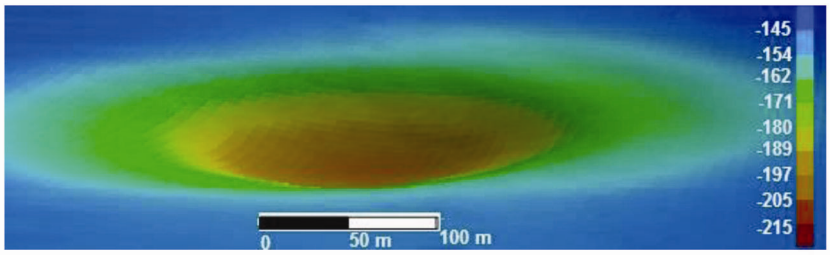

Figure 2. Multibeam 3D image of the depression located off Cochin, Arabian Sea.

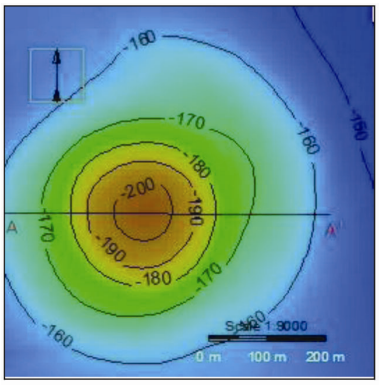

Figure 3. Multibeam 2D image of the depression (contours are isobaths and represent the depths below the sea floor) located off Cochin, Arabian Sea.

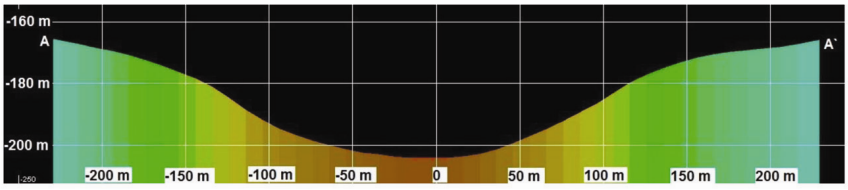

Figure 4. Multibeam E–W profile of the circular depression off Cochin, Arabian Sea.

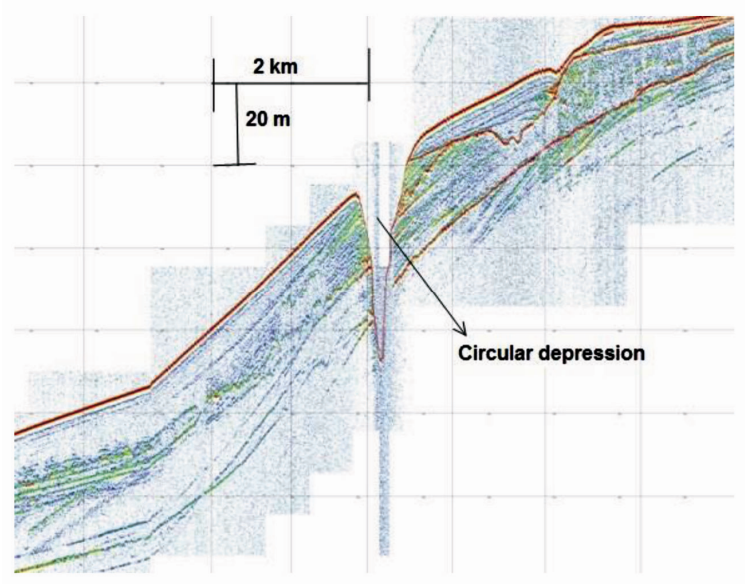

Figure 5. Sub-bottom profile of the depression off Cochin, Arabian Sea.

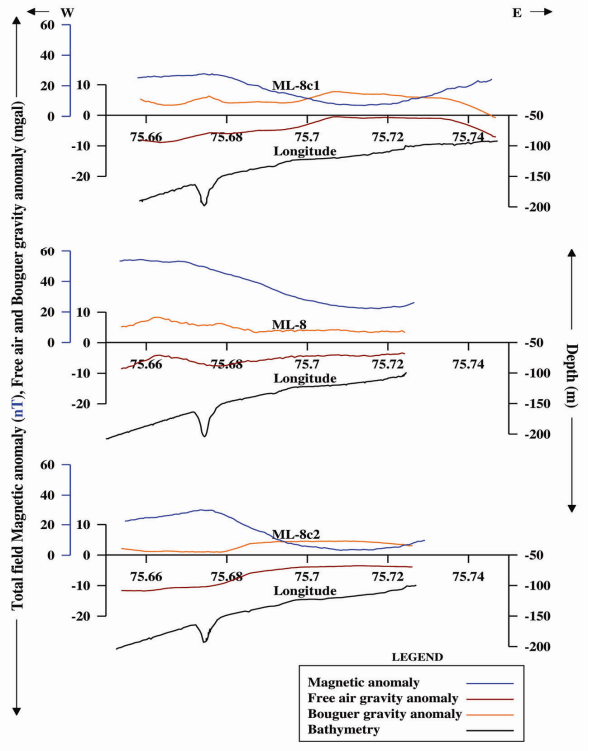

Figure 6. Magnetic, gravity and bathymetry profiles across the circular depression off Cochin, Arabian Sea.

geologic structure consists of the Bombay High and Surat Depression. They lie beneath the Indian continental shelf and the Indian Ocean west of Mumbai, India. However, definite indication for an impact has not been identified from the area.

The location of the depression reported here was either exposed during the Last Glacial Maxima or was at a very shallow depth at that time, and a depression formed 18,000 yr BP will not be preserved in the shape as seen today. This points to a very recent origin (Holocene) to the structure reported in this study. The sedimentary layers appear truncated sharply in the sub bottom profile (Figure 5). The depression has a smooth rim without any indication of an upturned ridge at the rim, which is an expected feature in impact craters. It is possible that upturned ridge is masked by subsequent sedimentation. Negative magnetic anomaly occurs over any impact crater since it destroys the original magnetic fabric of the area[9,10]. But because the zone is having thick sediment cover and low magnetic values, the effect of impact, if any, has not been observed.

There are some significant features which are to be analysed. First, the positive magnetic anomaly over the depression extending to the deeper sea in all the three profiles (Figure 6). This is possible if some high magnetic materials are present in the depression. Second, free air gravity anomaly generally mimics the bathymetry and should have a low over the crater but surprisingly has no effect on the profiles. It is possible only, if some high density material counteracts the lows due to depth. Since meteorites are having high density and magnetic susceptibility, the geophysical data implies that the depression is possibly an impact crater. However, the study of coarse fractions of sediment from the 12.5 m long core taken from the centre of the depression did not yield any minerals indicating shock metamorphism. But this need not be taken as evidence against impact crater since the core is not very deep which might not have reached beyond the zone of sediments filled in after the formation of the crater. Though the depression is inferred as an impact crater, more studies are necessary for its confirmation. Proximity of the depression to an E–W trending fault suggests the possibility of it being a pock mark which also should be explored. Only a muti-beam survey in the shelf area, east of the depression can confirm whether any such features exist in the vicinity. Multi-channel seismic profiling can bring out more information about the subsurface configuration of the feature. Re-examination of the depression with Remotely Operated Vehicle is suggested for locating any gas venting structures inside the circular depression and for collecting samples for gas chromatographic examination of the sediment for possible indications of natural gas emanation.

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