establish a gregarious growth pattern despite browsing and commercial exploitation in the latter.

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ACKNOWLEDGEMENTS. We thank Prof. H. Y. Mohan Ram for taking efforts to improve the manuscript; Dr T. S. Nayar and Dr C. Sathish Kumar for helpful suggestions, and N. Salahudeen and K. Asokachandran Nair for assistance during fieldwork. The Western Ghats Cell, Planning and Economic Affairs Department, Government of Kerala is acknowledged for funding the work under the Western Ghats Development Programme.

Received 29 June 2009; revised accepted 31 August 2010

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Stationary magnetotelluric monitoring system for earthquake research in Koyna region, Maharashtra

Strong earthquakes usually lead to crustal scale deformations, which in turn are caused by the large stress accumulation over a long period of time (a few decades). The recent major devastating earthquakes in India – Bhuj earthquake in Gujarat[1], Jabalpur earthquake in Madhya Pradesh[2] and Latur earthquake in Maharashtra[3,4] – have changed the notion that stable continental regions of India are not prone to major earthquakes and have demanded more stable examination of the stress accumulation. Another factor of concern to the Indian earth scientists is the continuous seismic activity in the Koyna–Warna region of Maharashtra located near major reservoirs.

Continuous seismic activity in the Koyna–Warna region has drawn the attention of many earth scientists in India and abroad especially due to its active nature since 1963. After the first known main earthquake near Koyna on 10 December 1967, the activity continued around 0.1 million earthquakes of low ($M < 4$) magnitude earthquakes[5]. A few (190) high-magnitude ($M > 4$) earthquakes have also been reported from the Koyna–Warna region. Interestingly, these earthquakes occur in a small region of 25 × 10 sq. km. This region is also well-mapped for the existence of faults and has become an ideal site for initiating the earthquake-monitoring experiment to understand the physics of occurrence and also for protection. Many geophysical studies like GPS, gravity variation, pore pressure, radon gas leakage measurements, etc. have been initiated for monitoring the earthquakes. In this direction, magnetotelluric (MT) field measurements have also been taken up with an aim to develop a forecast model for earthquakes in the region. It is reported that seismic activity causes ionospheric

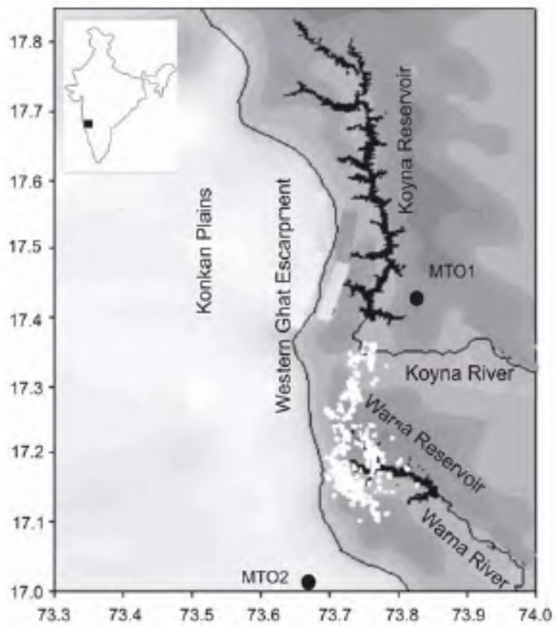

Figure 1. Location of the two magnetotelluric stations, MTO1 and MTO2, in Koyna along with locations of the two reservoirs – Koyna and Warna. Distribution of earthquake epicentres for 1996–97 in Koyna is shown as white dots. Sharp changes in the surface elevation with the Western Ghats in dark colour as a boundary can be seen.

conductivity variation[6,7]. It is also reported that sub-surface conductivity changes to an extent of 10–15% over a period of time in the earthquake hypocentral region[8]. In order to monitor ionospheric changes and also sub-surface electric conductivity variation over a period of time, the present experiment was taken up to observe magnetic and electric field variations through semi-permanent stations at two locations near Koyna.

Horizontal orthogonal components of electric field and three components of magnetic field were recorded as a function of time. From the measurements of electric and magnetic field variations one can derive the impedance Z that can be written as $E = ZH$, where E and H are the electric and magnetic field components in frequency domain. In general, Z is estimated from different combinations of the spectra of electric and magnetic field variations. The depth of study is achieved from the impedance estimation for a wide band frequency. Higher frequency provides information at shallow depths and lower frequency at great depths. Typically, in the frequency range of 1000–0.001 Hz, one can scan the earth from the depth of 5–10 m to 50 km in the Koyna region confidently.

In a remote reference system[9], it has been shown that the cross powers of electric and magnetic fields of the local station with respect to the remote station reduce the bias errors in the impedance estimation. In our study, we present the results of the two established MT systems for continuous monitoring. The results have been derived by processing the data as a single station and also as a remote station and compared.

Unlike measurements of MT signals, which usually extend for a period of 2–3 days in exploration programmes, the stationary MT systems are planned for a duration of 3–5 years and thus demand special attention. Figure 1 shows the location of two broadband MT stations – MTO1 towards east of Koyna reservoir and MTO2 towards west of Warna reservoir. These stations are located in the same geological unit of the Deccan traps, on either side of the earthquake epicentre clusters, as shown in Figure 1. These stations were established in July 2007 at Patan (MTO1) and in February 2008 at Devrukh (MTO2). The locations were chosen from a pre-field survey to avoid cultural noise. As there is no electric power supply at the stations, the instruments are powered by six lead acid batteries (2 V, 600 AH). The batteries are continuously being charged using solar power with photovoltaic panels with an output power of 400 W. The solar panels are fixed on the roof tops of the buildings. For data transfer from these two stations to Hyderabad located about 600 km east of Koyna region, we have used a novel technology using GSM network. From pre-field survey, the signal strength of the various vendors providing mobile-phone networks was assessed at the two stations. The MT instrument has a provision to insert GSM sim cards (popularly used in mobile phones). After powering the system and during operation, the system automatically sends the data to the server at Hyderabad using internet protocol for every 1 h or earlier. We can also control the systems from a remote place like Hyderabad. For a similar facility, the present seismic observatory network uses V-Sat network and a large antenna of 2–3 m diameter.

As an example, the data acquired for a period of one month at both the locations have been processed by remote referencing (Figure 2). For remote reference analysis, data from MTO1 were considered as the local station and MTO2 as a remote station and vice versa. As can be seen, the resistivity of the Deccan traps

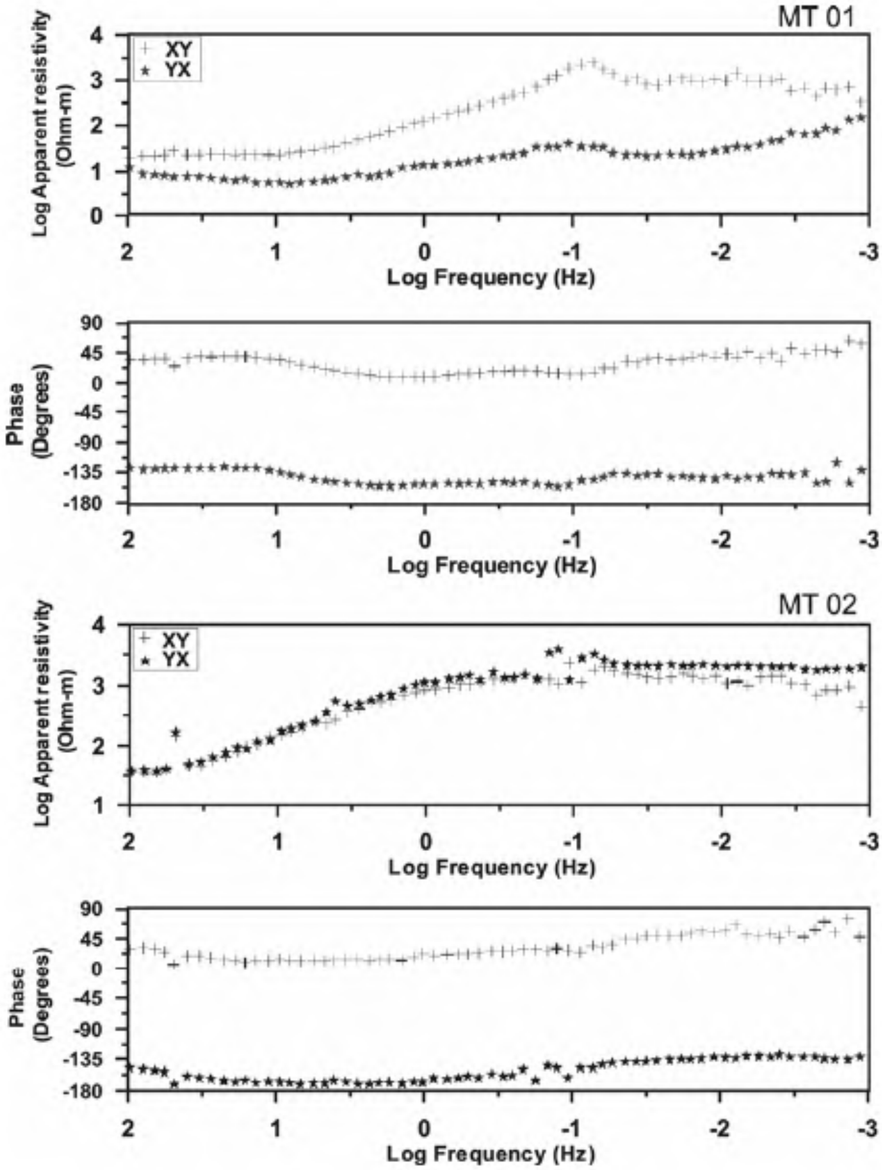

Figure 2. Apparent resistivity and phase curves for the two sites processed in remote reference mode.

is of the order of 10–20 ohm.m near the station MTO1 and 50–60 ohm.m near the station MTO2 followed by gradual increase in the resistivity, indicating qualitatively that the traps lie directly over the resistive basement. There is a gradual decrease in the apparent resistivity curve for frequencies greater than 0.1 Hz for both the stations, indicating the conductive mid-lower crust in the region.

Since the establishment of continuous monitoring MT stations, four earthquakes with magnitude $M > 4$ have been observed. From the preliminary observations and analysis of the time series signals, no perceptible changes in the signals were noticed that could be reported as precursors. However, distinct variations of the signals were observed at the same time of arrival. These can be considered as co-seismic signals.

Simple 1D modelling of the MT data for the two stations has been carried (Figure 3). For this purpose, arithmetic mean values of the apparent resistivity and phase data of *xy* and *yx* components were considered, and Marquardt inversion algorithm[10] as well as Occam inversion algorithm[11] have been used. As can be seen from Figure 3, the Deccan traps with a resistivity of 20–30 ohm.m and a thickness of over 800 m lie directly over a high resistive (800 ohm.m) basement for the station MTO1 located near Patan. For the station MTO2, the trap resistivity exhibits slightly higher values (40–50 ohm.m) compared to MTO1. The thickness of the traps estimated to be 300 m near MTO2 compared to 800 m near MTO1. Variation of trap thickness and trap resistivity on either side of the Koyna fault indicates the active nature of the region even during upper Cretaceous–Miocene times. Such variations in trap parameters have also been reported in an earlier regional study[12] of the region in an east-west profile. In this regional study, conductive fluid has been reported at upper–mid-crustal region from 2D modelling of MT data. This indicates the active nature of the region not only due to man-made activities like construction of a major dam, but also due to underlying disturbed deep tectonic structure within the seismically active zone.

In summary, two MT stations have been established near Koyna–Warna region for continuous monitoring of electric and magnetic field variations over a frequency band of 900–0.00033 Hz using a V8 MT system (M/s Phoenix, Canada). Preliminary analysis of time-series data, spectral data, impedance estimation and also apparent resistivity and phase parameters show that there is no perceptible variation observed which can be claimed

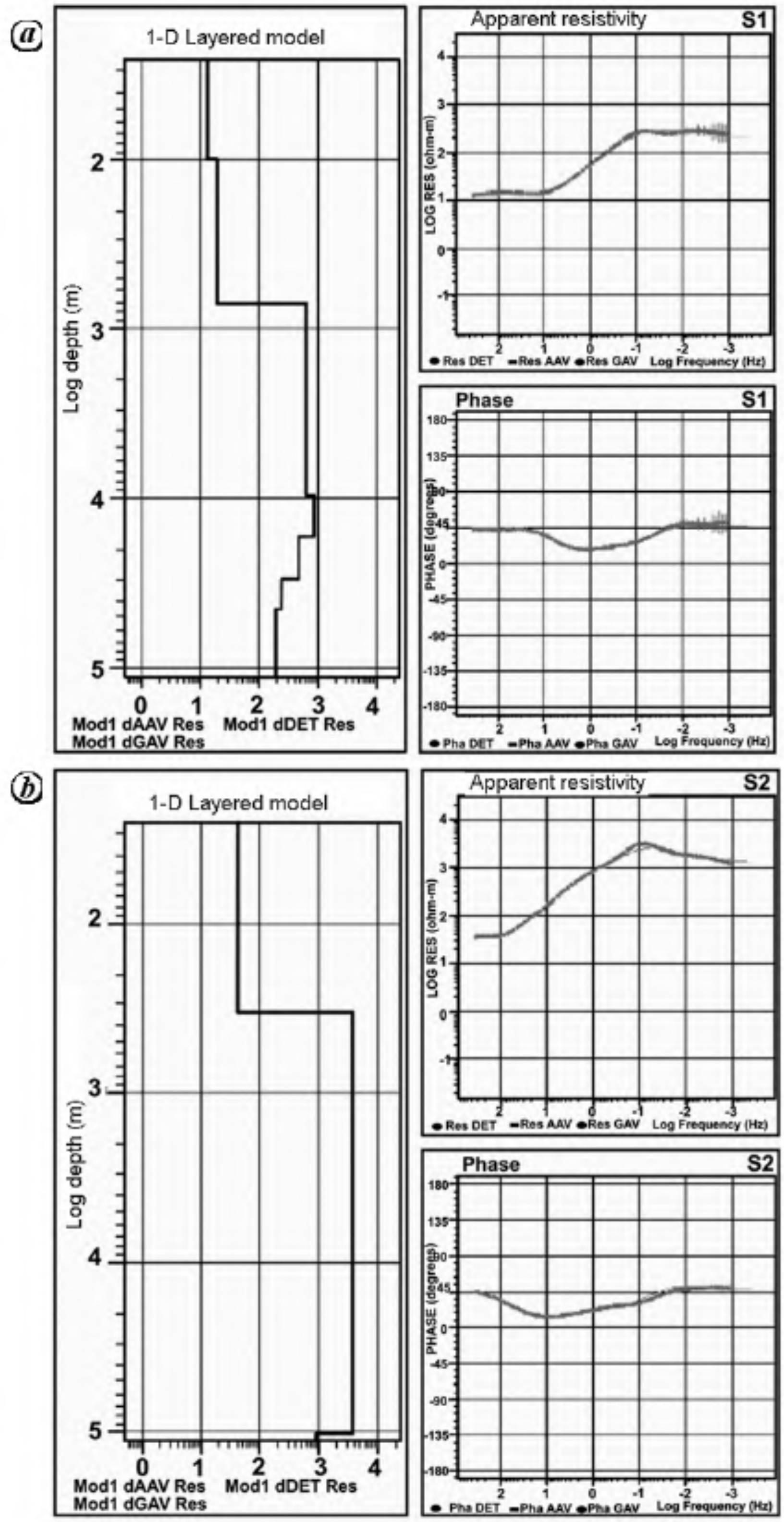

Figure 3. Resistivity and depth parameters estimated from 1D model for the stations MTO1 (***a***) and MTO2 (***b***).

as a distinct precursory phenomenon related to the occurrence of earthquakes with a magnitude $M > 4$ and $M < 5$. However, distinct variation has been observed at the same time of origin of the earthquakes, which can be considered as co-seismic activity. Detailed data analysis is in progress to locate precursory phenomena, if any, related to earthquakes.

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ACKNOWLEDGEMENTS. We thank the Director, National Geophysical Research Institute, Hyderabad for support and also for permission to publish it. We also thank MoES, Government of India for funds.

Received 29 March 2010; accepted 26 August 2010

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Expression analysis of *β*-actin promoter of rohu (*Labeo rohita*) by direct injection into muscle

The cytosolic *β*-actin is expressed ubiquitously and abundantly in almost all eukaryotic undifferentiated and differentiated cells[1]. The *β*-actin promoter of several fish species has been cloned, characterized and subsequently used for generating transgenics[2–6]. The use of 'autotransgene' construct, where both the promoter/regulatory element and targeted structural gene derived from the same species, was demonstrated to be beneficial in transgenesis[7]. This requires isolation of species-specific functional promoter capable of driving either ubiquitous or tissue-specific expression of the gene of interest. The Indian major carp, *Labeo rohita*, popularly known as rohu, is an economically important freshwater fish in India as well as other Asian countries[8]. Isolation of rohu *β*-actin promoter will have potential use in expressing desired genes of interests for generating transgenic rohu. The transgenic approach is a rather time-consuming process for verification of functional activity of the isolated promoter. Muscular injection of naked plasmid DNA has proved to be a simple, efficient and quicker method of functional validation[4,9–12]. In the present study, we have isolated rohu *β*-actin 5′-upstream region and identified promoter/regulatory regions. Functional validation of the promoter was carried out by direct injection into the rohu skeletal muscle.

Genomic DNA was isolated from the liver of rohu as described earlier[8]. The *β*-actin 5′-flanking region containing promoter, untranslated exon1 and intron1 was derived using GenomeWalker Universal Kit (Clontech) according to the manufacturer's instructions. The gene-specific reverse primers GSP1 (5′-GGGAGCATCATCTCCAGCGAATCCGGCTTTGC-3′) and nested GSP2 (5′-CACATACCGGATCCGTTGTCAACAACCAGTGC-3′) were designed from the coding exon2 sequences of *β*-actin available for rohu and other species in the GenBank. The upstream adaptor primers AP1 and nested AP2 were supplied along with the kit. Four independent *Dra*I, *Eco*RV, *Pvu*II and *Stu*I digested genomic DNA libraries were generated. The cycling parameters for touch-down PCR were five cycles at 94°C for 25 s and 72°C for 3 min followed by 20 cycles of 94°C for 25 s and 69°C for 3 min. A 1.6 kb fragment amplified from the *Stu*I library was cloned into a pGMET-easy vector (Promega) and bidirectionally sequenced in an automated ABI 310 genetic analyser (Applied Biosystem). The sequence data were submitted to GenBank (accession no. GU338376). The sequence data analysis by MatInspector 7.4.3 of Genomatix Inc. (http://www.genomatix.de/products/MatInspector/index.html) revealed that the 5′-flanking region contained exon1 and intron1, including consensus

Table 1. Sequence comparison of rohu *β*-actin promoter and regulatory regions with other related species

Species	Percentage of homology	Accession number
Catla (*Catla catla*)	96	AF415205.1
Common carp (*Cyprinus carpio*)	85	M24113.1
Grass carp (*Ctenopharyngodon idella*)	88	M25013.1
Mud carp (*Cirrhinus molitorella*)	94	DQ241809.1
Zebrafish (*Danio rerio*)	93	EF026002.1