Table 5. Effect of various media on somatic embryo maturation in three established cell lines (R-1, R-3 and R-29) of *P. roxburghii.* The embryogenic culture clumps were first transferred to hormone-free half-strength DCR basal medium for one week before transferring them to maturation medium

	Embryogenic cell lines		
Medium*	R-1	R-3	R-29
10 μM ABA + 0.18% gellan gum	54 (4)[#]	46 (0)	38 (2)
30 μM ABA + 0.18% gellan gum	45 (7)	38 (3)	47 (4)
30 μM ABA + 0.25% gellan gum	38 (13)	47 (8)	52 (18)
0.30% gellan gum	28 (0)	35 (0)	42 (1)
Control	0 (0)	0 (0)	0 (0)

*All media contain half-strength DCR basal salts[16] + 2% sucrose + 1.0 g l^{-1} myo-inositol.

[#]Data represent number of clumps of embryogenic cell lines cultured on different media combinations; Data within parentheses represent the number of clumps of embryogenic tissue showing somatic embryo formation. (Weight of each clump of the embryogenic mass varied from 320–550 mg).

embryogenic tissue for the development of somatic embryos to plants.

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On the occurrence of small and moderate earthquakes of the Himalayan Seismic Belt

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Small and moderate magnitude earthquakes occur along a narrow belt in the Himalaya[1–4]. The belt of these earthquakes, referred to as the Himalayan Seismic Belt (HSB), lies close to the surface trace of the Main Central Thrust (MCT)[1,4,5]. It coincides with the topographic front between the Lesser and Higher Himalaya[1], the zone of increased gradient of the Himalayan rivers[6], high interseismic elevation change rates deduced from repeat levelling measurements[7–11], and the high conductive feature beneath the southern Higher Himalaya[12]. The hypocentres of these earthquakes mark the inferred downdip edge of the main thrust zone (MTZ)[5,8,10,11]. In this article, we suggest that the earthquakes of the HSB occur as a result of strain accumulation on the MTZ. Our simple calculations of change in static stress[13–16] due to strain accumulation on the MTZ suggest that the static stress increases on the gentle planes above and close to the downdip edge of the MTZ, facilitating the occurrence of these earthquakes.

ABOUT 35% of the convergence between the Indian and Eurasian plates is accommodated in the Himalaya[8] through slip on the major intra-crustal thrust fault, the detachment[1,2]. This fault is referred to as the Plate Boundary Fault (PBF) with the Indian shield and the Himalayan wedge rocks[10,11] as its footwall and hanging wall, respectively. The slip on the PBF that lies under the southern Higher, Lesser and Outer Himalaya, occurs episodically during the occurrence of great and major earthquakes[1,2,8,10,11]. This part of the detachment is referred to

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*For correspondence. (e-mail: postmast@csngri.ren.nic.in) as the Main Thrust Zone (MTZ)[10,11]. During the interseismic period, the MTZ remains locked due to which strain accumulates for the great and major earthquakes whose ruptures lie on the MTZ[1,2,8,10,11]. The small and moderate magnitude earthquakes occur close to the inferred downdip edge of the MTZ[5,10,11]. Further downdip of the MTZ, the PBF slips aseismically and does not contribute to any strain accumulation[8,10]. In this communication, a brief overview of the occurrence of these earthquakes and other associated features is presented and also an attempt has been made to correlate the occurrence of these earthquakes to the strain accumulation on the MTZ.

Over most of the Himalaya, especially east of 78°E longitude, the epicentres of well located intermediate magnitude earthquakes lie in a narrow belt along the boundary between the Higher and Lesser Himalaya[2]. Hereafter we shall refer to this belt as the Himalayan Seismic belt (HSB). The belt coincides with the topographic front between the Lesser and Higher Himalaya and criss-crosses a major tectonic feature, namely the Main Central Thrust (MCT)[1,2,4], suggesting that the HSB probably has no relation with it (Figure 1). The HSB and the topographic front approximate an arc of a circle with a radius of about 1700 km in the map view[2]. Ni and Barazangi[3] redetermined the focal depths of 28 moderate magnitude earthquakes using the depth phases and waveform modelling. The revised estimates of focal depths were between 10 and 20 km invariably. The hypocentral locations of these earthquakes, when plotted on a composite cross-section perpendicular to the trend of the Himalaya, define a narrow, gently northward dipping zone with a downdip width of about 30–50 km (refs 1–4, 17). The fault plane solutions of these earthquakes showed that one nodal plane in each case has a gentle northerly dip under the Himalaya[3] (Figure 1). Similar conclusions were drawn also from the analysis of small and micro earthquakes recorded at the local networks[4,5]. Khattri *et al.*[4] and Pandey *et al.*[5] reported the results of micro earthquake surveys conducted in the Garhwal and Nepal Himalaya, respectively. The belt of local earthquakes located by these networks coincides with the HSB and the majority of the earthquakes occur at depths shallower than 20 km (Figure 1).

Jackson and Bilham[7] reported the interseismic elevation change observations along a levelling line that crosses central Nepal. The line passes through the northern Indo-Gangetic plains, Outer, Lesser and southern Higher Himalaya. The important feature of these observations is that the highest rate of interseismic elevation change coincides with the HSB (Figure 1). Similar interseismic elevation change rates have been reported along the Pathankot–Dalhousie levelling line in the Punjab Himalaya[9,11]. However, in this region the earthquake activity is quite diffused, partly due to large errors in the locations of epicentres and partly due to its proximity to the western Himalayan syntaxial bend[11]. Nevertheless, the highest rate of interseismic elevation change is at the northern end of the line, which approximately coincides with the HSB. Unfortunately, the elevation change observations further north of Mussoorie along the Saharanpur–Dehradun–Mussorrie levelling line in Garhwal Himalaya[18,19] are not available so far and hence we do not have quantitative evidence of high rate of interseismic elevation change close to the HSB in this region. In any case, the available

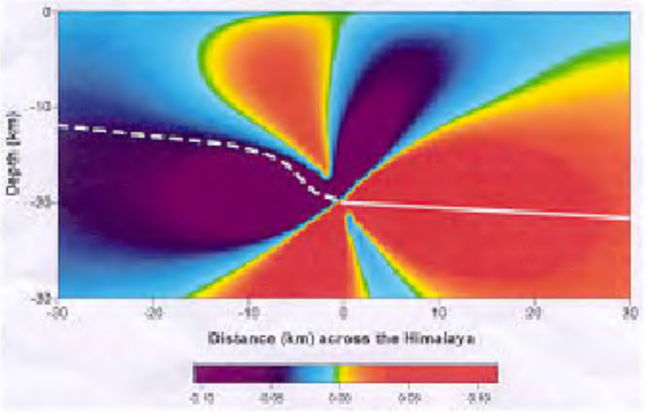

Figure 1. Schematic N-S cross-section of the Himalaya, showing a summary of available observations from the Himalaya, namely (i) the general trend of the interseismic elevation change rates, along with the rate uncertainties, deduced from the levelling observations in Punjab and Nepal Himalaya[7,9], (ii) the location of earthquake hypocentres[1–5] (circles, the intermediate magnitude earthquakes and dots, microearthquakes), and (iii) the zone of the conductive feature deduced from the MT studies in the Nepal Himalaya[12]. The approximate location of Figure 2 is also shown.

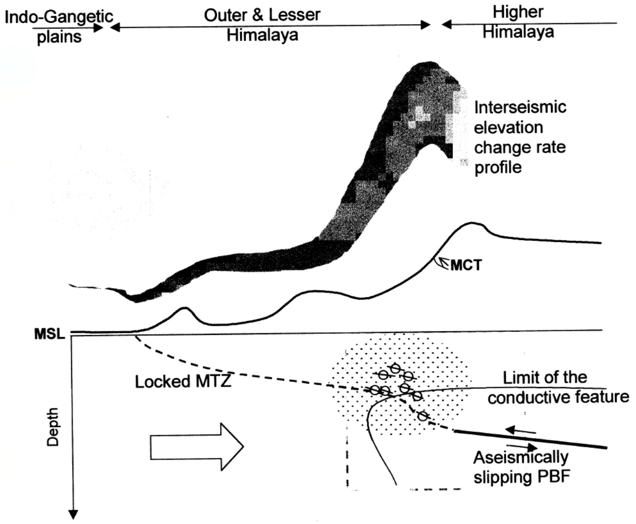

Figure 2. Calculated Coulomb stress changes (in bars) in the region under the northern Lesser and southern Higher Himalaya due to the strain accumulation on the MTZ (shown with the dashed line). Note the increased stress in three distinct zones. The stresses have been calculated on the planes having a gentle dip of 7° and for the coefficient of friction (μ) as 0.4 and Lamé's constants, G and λ as 3.2×10^5 bars each[14]. The downdip edge of the locked MTZ is at 0 km on the abscissa. The solid line shows the aseismically slipping PBF.

limited data do not contradict this observation in the first instance. The elevation change rates along the levelling lines in the Nepal and Punjab Himalaya have been explained as a result of strain accumulation on the MTZ[8,10,11]. The high rate of elevation change and the reliable focal depths of the earthquakes of HSB occurring close to the levelling lines, approximately lie close to the downdip edge of the MTZ in each region[5,8,11].

Seeber and Gornitz[6] examined the longitudinal profiles along sixteen major transverse Himalayan rivers and found that these rivers are characterized by relatively steep gradients through the Higher Himalaya and relatively low gradients downstream as well as upstream. The downstream edge of the zone of increased gradient correlates with the topographic front between the Higher and Lesser Himalaya, and with the HSB. Lamonnier *et al.*[12] have reported the results of MT studies across central Nepal and inferred a major conductive feature beneath the southern front of the Higher Himalaya (Figure 1). The spatial location of the conductive feature coincides with the intense earthquake activity. They interpreted that the high conductivity feature is due to the release of metamorphic fluids during underthrusting of the Indian shield rocks and building up of interseismic stress. Hence, it is possible that the above interrelated features, especially the occurrence of earthquakes along the HSB, may be due to the strain accumulation on the MTZ during the interseismic period.

In recent years, several studies related to the change in static stress due to the earthquake occurrence have been reported. These studies have been useful in explaining the spatial distribution of aftershocks[13,14], identification of the possible region for the next earthquake[15], evolution of stress in a region[16], effect of past earthquakes on the future earthquake occurrences[20], etc. We use this concept to explain the occurrence of earthquakes of HSB due to strain accumulation on the MTZ, assuming that the MTZ is locked. The process of locking on MTZ is obtained by superimposing a virtual normal slip on the MTZ and steady slip on the entire PBF[16]. The deformation caused by the above model is equivalent to the model in which it is assumed that the section of the PBF which lies immediately to the north and downdip of the MTZ, behaves as an elastic dislocation that slips by thrusting motion at a local plate convergence rate[8,16]. Thus, while the MTZ remains locked during the interseismic period, the PBF further downdip of the MTZ slips aseismically. For our calculations, we made simplifying assumptions that the depth of the updip edge of the aseismically slipping part of the PBF under the Himalaya is about 20 km and it has a dip of about 7° towards north[1–3,8,10,11]. It slips at a rate of 20 mm/year by thrusting motion[8,10]. We have adopted the elastic dislocation formulation method of Mansinha and Smylie[21] to compute the displacement field due to a finite fault embedded in an elastic half space. The stress components are calculated after taking the numerical derivatives of the displacement field. The obtained values of changes in stress components due to slip on the PBF were then used to calculate the change in normal and shear stress at a given fault plane. Following King *et al.*[13] and Nostro *et al.*[20], the change in Coulomb Failure Function, ΔCFF which is based on the Coulomb failure criterion for shear failure[22], is given by the relation

$$\Delta\mathrm{CFF} = \Delta\tau - \mu\Delta\sigma_n,$$

where $\Delta\tau$ and $\Delta\sigma_n$ are the changes in shear and normal stresses and μ is the coefficient of friction. The change in shear stress is computed in the direction of fault slip. To test our numerical procedure for the calculations of ΔCFF, we reproduced Figures 1 and 2 of Nostro *et al.*[20].

Figure 2 shows the change in static stress or the change in Coulomb Failure Function due to locking of the MTZ in the interseismic period. The changes in the static stress have been calculated on the planes having a dip of about 7° towards north. These planes simulate the fault planes of moderate and small magnitude earthquakes. It can be seen in Figure 2 that due to the strain accumulation on the MTZ, there is an increase in the static stress in three distinct zones. However, in the present work, we are interested in the region that lies above the downdip edge of the MTZ, in the depth range of 0 to 17 km. This region of increased stress approximately coincides with the region of occurrence of small and moderate magnitude earthquakes of HSB that occur on the gentle planes. This region may further be refined, so that it exactly coincides with the HSB, by assigning an appropriate slip function on the PBF and changing the geometry of the PBF and the ramp. However, in view of the several unknowns we avoid doing this and present the calculations based on a very simple model.

The increase in the static stress above and close to the downdip edge of the MTZ suggests that the gently dipping fault planes of that region will be encouraged (moved toward failure) to slip. Thus the increased stress due to strain accumulation on the MTZ facilitates the occurrence of earthquakes of HSB. Elsewhere, it has been suggested that the strain accumulation on the MTZ also explains the interseismic geodetic observations[8,10,11] and high conductivity of the subsurface rocks[12].

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Quantitative estimation of proteolytic enzyme and ultrastructural study of anterior part of intestine of Indian major carp (*Catla catla*) larvae during ontogenesis

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Specific proteolytic enzyme activity and ultrastructure of the anterior part of the intestine of *Catla catla* larvae were studied during ontogenesis. Specific proteolytic activity of larvae cultured under three feeding schemes of live-food, refrigerated-plankton food and starvation showed that the enzyme activity increased along with age regardless of feeding conditions. There was no significant difference in enzyme activity between larvae fed live-plankton and refrigerated-plankton during the initial 9 days, but it became significantly ($P < 0.001$) higher in the former than the latter from day-10 onwards. Highest activity was observed in the 26-day larvae of live-food treatment (0.987 ± 0.02 mg of tyrosine/mg of protein/h). In the starvation treatment, activity was significantly lower throughout the culture period. Ultrastructure study of the digestive system also supported the results of quantitative estimation. Microvilli, microfilament bundles and secretory granules showed progressive changes along with age. Age-related changes in the diversity and quantity of digestive enzymes appear to represent evolutionary adaptations to the different natural diets and nutritional requirements of distinct life-history stages.

THE digestive system and its physiological consequence in fish larvae seems to be a key parameter to understand basic aspects of larval nutrition. A comprehensive analysis of ontogenetic changes occurring during the early life stages of fish is essential for the design of adequate larval rearing and feeding strategies and for the formulation of dry diets[1]. Information on the relative digestive enzyme activities during early ontogenesis should ensure that the fish culturist develops proper feeding strategies for a particular species. It is known that age and/or stage of development significantly influences the digestive enzyme activity in different species[2–8].

Indian major carp, *Catla catla* (catla) is the most important commercial fish in India. It has a high market demand. High larval mortality of this species under nursery conditions is the result of its dependence on live-food[9,10]. The intestinal tract of fish larvae is much more simply organized and shorter than that of the adults[11]. This may explain the generally carnivorous feeding habit of fish larvae, even those of herbivorous species[7].

Although several descriptive reports are available on the morphology and anatomy of the digestive system of adult Indian major carps[12–14], little work[15,16] has been done on the early ontogenetic changes of the digestive enzymes of Indian major carp larvae and no work has been reported on their ultrastructure till now. The aims of the present investigation were quantitative estimation of proteolytic enzyme in the digestive system and the ultrastructure study of the anterior part of the intestine of *Catla catla* along with ontogenetic development.

Catla larvae (3-days post hatch) were procured from a fish farm having induced breeding facility. Larvae were cultured (500/15 l aquarium) under closed recirculating system for 26 days. The average standard length and weight of 4-day-post hatch larvae were 6.3 ± 0.21 mm and 0.79 ± 0.01 mg, respectively. Larvae were cultured under three different feeding schemes of (1) exogenous introduction of live-food, (2) exogenous introduction of refrigerated-plankton food and (3) starvation. Three replicates were maintained for each feeding scheme. Qualitative estimation of plankton showed the dominance of *Cerio-*

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