ing, nearby resorts and convention centres. It co-ordinates for various institutions seeking conference venues in this much sought after exotic location. This strengthens local economies and helps global sharing of knowledge.

Other activities worth mentioning are the VLSI design and development, and the Ocean Science and Technology Cell (marine microbiology) in collaboration with the Department of Ocean Development (DOD). Finally, with Konkani being the language spoken by the Goans, a Centre for Konkani Development Studies has been started recently.

Goa University has arrived on the education scene as a role model, a trendsetter of sorts.

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RESEARCH NEWS

Discovery of life in greater than 2.6 billion-year-old terrestrial samples

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The origin of life on earth and its progress, intervened by bouts of evolution and extinction over earth's long history, continue to be among the major topics discussed by scientists. Earth's life, as very simple forms, began in the ocean, during very early Archaean[1–4], more than 3.8 billion years (b.y.) ago, though its proliferation to multicellular forms commenced much later, in late Proterozoic period[5] (Figure 1). Archaean life has been discovered mostly from marine strata and although organisms were expected to have colonized lands also (terrestrial life)[3–7], no authentic findings were reported from any non-marine strata older than the mid-Ordovician–Silurian (500–400 m.y.) period[8]. This had led to the belief that life on land had appeared much after it did in the ocean, an assumption arising possibly due to paucity of evidences. This view may require a revision now in the light of fresh findings.

Life could perhaps have developed on land at about the same time as it did in the ocean, but for the fact that it took some time for the continental crust to remain stable to support life (oldest stable crust: 4–4.03-b.y-old tonalites and granodiorites, Acasta area, Canada)[9,10]. Processes like remelting of early formed crusts or their recycling back into the mantle accompanied by vigorous volcanism and tectonism dominated the scene. Meteorites continued to bombard, their destructive impact more severe on terrestrial, rather than on the oceanic life. Besides, earth went through five ice ages during the Precambrian, one or two of which covered the entire globe with ice[11,12] (Figure 1). The composition of early atmosphere was inhospitable as it was rich in CO_2, N_2, H_2, NH_3, and CH_4, and significantly, it was almost oxygen-free ($\leq 1\%$ present atmospheric level before 2.2 b.y. ago)[13]. The little oxygen produced was used up in oxidation of iron-bearing minerals, volcanic gas and organic matter and the early atmosphere was therefore reducing[14]; but current researches have come up with data doubting this view[6,15,16]. More importantly, in the absence of O_2, the ozone-shield could not develop to protect life from the lethal UV radiation from the sun, though a few organisms were known to have evolved shielding strategies[17].

Despite all these hostile conditions, the continental land areas of this period could not have been so bereft of life, as made out by the absence of evidences, since well-protected realms for life to thrive could still have existed. This inference is supported by characteristic $^{13}C/^{12}C$ ratios seen in certain Proterozoic palaeokarsts[13] as well as by the existence of forms of organisms that do not depend on O_2 (anoxic forms), like the sulphate-reducing bacteria and methanogens. In this search for early Precambrian life on land, certain geological strata are found to have good potential to preserve the evidences and also clues to the nature of the early atmosphere. Among such strata, the non-marine sedimentary beds or products of sub-aerial weathering like the *palaeosols,* which are buried and compacted ancient soils, are good examples. These beds are often present as unconformable layers in Precambrian terrains of the world. In India, there are extensive Precambrian formations and such breaks or hiatuses that intervene some of the classic sedimentary horizons here may be promising sites for locating early terrestrial life.

Since the 1980s, evidences of microbial activity on land, seen as trace fossils, spores, organic matter, in pre- and post 2.2 b.y. period, have reduced the seeming gap in emergence of life in ocean and land[8,18–23]. These are reported from paleosols and other weathering products (e.g. conglomerates, calcretes and dolocretes), as well as in freshwater. Among these findings, microfossils preserved in cavity fills in chert breccia occurring in 1.2-b.y.-old limestone in Arizona (USA), had remained the unambiguous earliest terrestrial life[8]. Recently however, organic matter in 2–2.7-b.y.-old Archaean palaeosol samples from eastern Transvaal, South Africa[24] has revealed that organisms like cyanobacteria existed on land even 1.4 b.y. earlier than the Arizona forms. These palaeosols, derived from

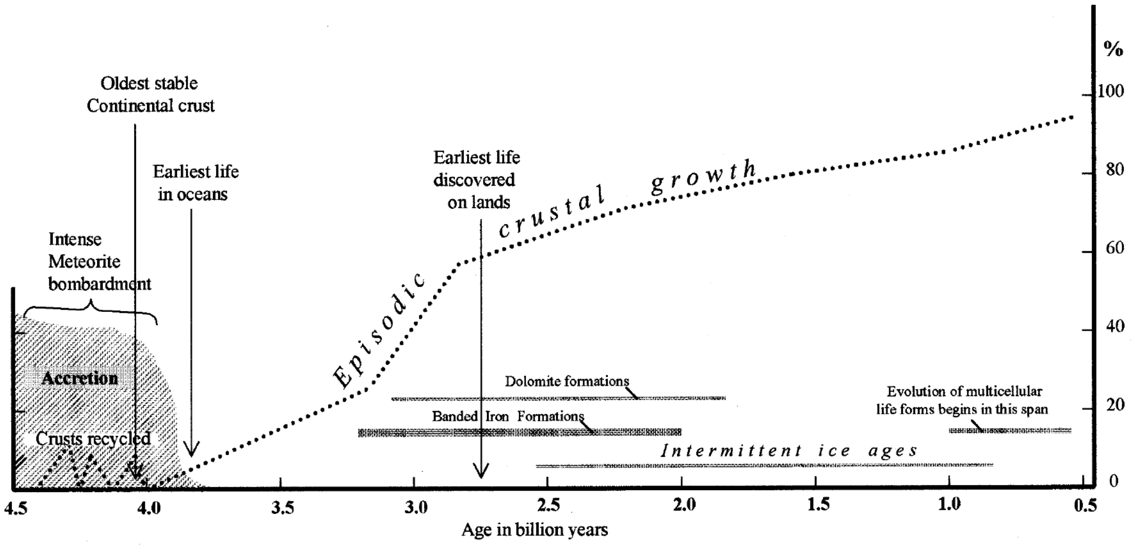

Figure 1. Geologic history of events with reference to life on earth (adapted from refs 32 and 33).

carbonaceous rocks under semi-arid conditions, are deposited over serpentinized dunite forming part of Archaean Basement Complex of granites, granitic gneisses and basalts.

The carbonate-rich paleosol layer (17 m thick) reported from Transvaal, lies between a 2.6-b.y.-old quartzite bed (~30 m thick) on its top and >2.7-b.y.-old serpentinized dunite at its bottom and hence must have formed between these periods. The carbonates, which are mainly calcite ($CaCO_3$) and dolomite [$CaMg(CO_3)_2$], associated with colloidal quartz and aluminum-rich clays, were precipitated from soil and/or groundwater and undoubtedly are non-marine in origin. The organic matter in the palaeosols carrying high carbon content (0.01–0.36 wt%) is visible only under an electron microscope intimately mixed with clay minerals (talc, chlorite, ferristilplomelane). These are seen as thin ribbons or seams (~ 30 µm–1 mm thick and 1 cm long) between quartz grains or as networks or clots around them. Textural and crystalline features of the organic matter and geochemical ratios of C, N and phosphates in it are typically biogenic and exhibit no correlation with carbon from disseminated graphite formed during the serpentinization of dunites >2.7 b.y. ago, or with liquid hydrocarbon (petroleum) introduced after soil formation. Besides, their occurrence intimately mixed only in clay-rich parts in the rock is claimed to be a strong indication that the organic matter is an *in situ* remnant of organisms. In the absence of any detectable sulphur in the environment of Transvaal palaeosols, these organisms are suspected to be oxygen-based, possibly surface microbial mats (photosynthetic organisms) which were transported downward by percolating waters[24].

In the last few years, quite a few studies have commented about the nature of the Precambrian atmosphere – whether oxic or anoxic. A very recent work[15] on a rare earth mineral rhabdophane (hydrous phosphate of Ce and Y) formed in a 2.6–2.45 b.y. palaeosol in Canada has revealed that the Ce^{3+} in this mineral remained unoxidized during the Precambrian weathering in contrast to its oxidation to form cerianite (CeO_2) in younger period weathering profiles, implying thereby existence of oxygen-poor conditions during early Precambrian. Occurrence of extensive banded iron formations (BIFs) in this period is generally cited as a strong evidence for oxygen-poor or reducing Precambrian atmosphere. However, a study on the behaviour of iron (as Fe^{2+}, Fe^{3+} and ΣFe) in pre-2.2-b.y.-old palaeosols has shown that the development of these BIFs was not because the atmosphere was reducing, but due to reductive dissociation of ferric hydroxide under an oxic atmosphere[6]. This reductive dissociation was caused by organic acids generated from decay of terrestrial organic matter, a proof for thriving terrestrial biomass on continents much earlier than hitherto believed[6,24,25]. If future discoveries prove this inference to be correct, they may indicate development of a life-protecting ozone shield in the atmosphere by 2.6 b.y. and by implication, presence of molecular oxygen[6,24]. In this context, it is relevant to take note of conclusions from carbon isotope mass calculations in several samples in the age span 3.0–2.1 b.y. from the Kaapvaal Craton, South Africa[16], which have indicated that the atmospheric oxygen was constant since 3.0 b.y. at a level comparable with Phanerozoic atmosphere. However, an assessment of the $^{13}\delta C$, crustal and atmospheric reservoirs of O_2, Fe^{3+} and SO_4^{2-} shows that the development and progress of oxic conditions in the earth were episodic[26], particularly in the Proterozoic period.

Thus a debate appears to be brewing presently about the nature of the atmosphere during early Precambrian. However, for the existence of life, an oxic atmosphere is not essential, since forms which derive their energy through other chemical routes can proliferate under anoxic or reducing atmosphere. In fact, the predominant dolomite formations in the early earth, it is now claimed, owe their existence to such anoxic forms like sulphate-reducing bacteria, which precipitated them during their metabolic activities (microbial mineralization), a view experimentally confirmed with such bacteria at low temperature anoxic conditions[27–30]. Indeed, as in the ocean[31], the latter forms of life must have been the pioneers to colonize *terra firma* also, before higher forms appeared. The developing research applying genomics to geosciences have placed the anaerobics close to the root of life and have shown that oxygen-inhibited nitrogen fixation existed even before last common ancestor of all living organisms and earth scientists are now awaiting more light from such studies on co-evolution of biosphere and atmosphere[34].

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