The community caring for its own food and water security

Land and human survival are intertwined. The use or misuse of land has altered soil profiles, threatening its role in serving the socio-economic need of its people. In a bid to help conserve land, a national Land Care Movement (LCM) was launched on 26 April 2001 with the meeting of the consultative group on land and water care (CLAW).

With its headquarters at M.S. Swaminathan Research Foundation (MSSRF), Chennai, CLAW would ensure 'promoting convergence and synergy among all concerned ongoing programmes and initiatives at the field level involving central and state government agencies, civil society organizations and bilateral and multilateral donors'. Some of the other players in CLAW are the Department of Land Resources (Ministry of Rural Development), Agriculture Ministry, Sir Dorabji Tata Trust, UNDP, FAO, World Bank, Ford Foundation, DFID and SCSI, to name a few.

Recommendations made in the New Delhi declaration on National Resource Management in November 2000 are specific to India's needs and pertain to policy, approach and strategy, recognizing land as a prime national resource, and water resources as finite, which need to be conserved, developed and managed. The strategy and approach call for a 'complete reorientation in attitude and work culture of existing organizations, government and non-government, making them nationally committed and scientifically updated, on a continuing basis'. Using a community-based participatory approach, it calls for providing women with land rights, wherever applicable. It also states that 'land records and reform should be up-to-date and transparent, with land ownership records computerized at different levels'.

Part of the regulatory agenda lies in preventing the use of agricultural land for non-farm use and protection of topsoil, while curbing the latter's use in brick manufacture with alternatives such as fly ash etc. Also, re-vegetation by social afforestation programmes in agriculturally marginal soils and restoring irrigation efficiency of disturbed lands such as mine spoils. Monitoring and evaluation aspects include transparent information posted annually on extent of drinking water shortage in villages, reduction of rain-fed areas, achievement of gender and social equities. 'Virtual' colleges, linking farming communities with scientists via interactive mode, secure transfer of scientific information as inputs for farmers and a bio-industrial watershed model integrating the processing at the village level, ensuring value addition and quality. For implementation, the choice rests on gram panchayats, as the apex community-based organization, self-help groups and target-oriented village level groups.

A community-oriented food and water security system for land resources associates rural knowledge centres in partnership with Panchyati Raj Institutions (PRI). Sustainable development involves integrated information management solutions, databases for support operations and decision-making.

How can the scientific community participate? For this, the recommendations are:

- Assess erosion impact on productivity (in economic terms) at farms, watersheds eco-regions and at a national scale;
- Evaluate off-site impacts of soil erosion in terms of water quality, air quality, emission of greenhouse gases and sedimentation of reservoirs and waterways;
- Develop indigenous prediction models and conservation measures;
- Determine soil carbon sequestration potential to mitigate the greenhouse effect through desertification control, restoration of degraded soils and ecosystems;
- Identify soil/land quality indicators which scientists can quantify and farmers can comprehend;
- Assess periodically (5–10 years), the state of natural resources (land, water and vegetation) at regional and national scale, using remote sensing and other modern techniques.

Further details are to be found in the discussion paper on 'Land care movement', MSSRF, Chennai.

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RESEARCH NEWS

Rise of atmospheric oxygen – New hypothesis on the role of Archaean–Proterozoic mantle

A. V. Sankaran

Among the events that shaped the evolution of the earth, the rise of molecular oxygen (O_2) in the atmosphere constitutes the most momentous happening, heralding the rise of terrestrial life. Until the commencement of the Proterozoic eon (2500–570 m.y.), the earth's atmosphere was almost devoid of this gas and the bulk of the life that existed derived its energy needs through anoxic chemical routes[1–4]. Though evidences for oxygen-synthesizing cyanobacteria, living as early as 2.7 b.y. are found in sediments[5,6], perceptible rise of O_2 in the earth's atmosphere appears to have taken place almost a billion years later. The significant developments in earth's history that led to this oxic trend have been discussed by many workers, but most of them dwelt more on the timing of this rise between 2.4 and 1.8 b.y., whereas the mechanisms that led to this rise did not receive adequate attention. Now, a new hypothesis advanced recently[7], covers the latter aspect and describes how the O_2-consuming processes (sinks) which were large during the Archaean, were cut down through changes in the structure and composition of late-Archaean and earliest-Palaeoproterozoic mantle, leading to the dramatic build up of O_2.

Presence or absence of O_2 in the atmosphere depends upon which half of the gain/loss cycle is dominant (Table 1). Oxygen-gain is achieved through processes like photochemical break up of water vapour in the atmosphere and photosynthesis by plants and bacteria. It is lost through weathering of rocks, reactions with gases from volcanoes, fossil fuel combustion and respiration by plants and organisms[8,9]. Presently, photosynthetic production of O_2 is able to independently equalize the losses and maintain atmospheric O_2 level at about a 21% (ref. 9), but the Archaean atmosphere was quite different. Intense volcanism, aided by relentless meteorite impacts, outgassed highly reducing H_2, NH_3, CH_4, CO_2, CO and N_2, which soaked up what little O_2 was produced photochemically[10,11]. In fact, the net loss of O_2 through surface volcanoes in those times was more than its production by a factor of 40, than the present time's[7]. Added to these, the few glacial spells that gripped the earth during Archaean–Proterozoic transition[12] led to atmospheric accumulation of oxygen-consuming CO and CO_2. This O_2 loss could not be made up in the absence of photosynthetic O_2-producing forms of life[1–3,13], which appeared on lands much later[5,14].

The oxygen-poor status of Archaean and early Proterozoic atmosphere is also reflected in the sedimentary deposits carrying detrital concentrations of uraninite (UO_2) and pyrite (FeS_2). These minerals are known to be unstable in the presence of O_2 and hence their occurrence, unaltered in these deposits, is considered proof of O_2 paucity during those times. Other geological records like red-beds (Fe-oxides) and banded iron deposits (BIFs) also point to this state of the earth's atmosphere then. Red-beds form when Fe in the rocks is oxidized during sub-aerial weathering[15] (surface oxidation) and hence their occurrence, mainly after 2.0 b.y. reflects the rise of O_2 thereafter only. BIFs occur exclusively in pre-1.85 b.y. period and iron for these deposits came mostly from under-sea volcanic vents and to a lesser extent from surface rocks. Iron, as water-soluble form, Fe^{2+}, from these sources, accumulated in the anoxic bottom zones of the oceans where they remained stable. Their precipitation later, as insoluble ferric iron (Fe^{3+} in hematites of BIFs), took place when ocean currents, upwelling intermittently, brought them to near-surface zones oxygenated by certain forms of O_2-producing bacteria thriving there[11] or when these O_2-rich waters were carried to the bottom zone by down-welling currents[16]. Apart from these classic examples, new geologic evidences are also coming up, establishing rarity of atmospheric O_2 during Archaean period. For example, cerium in the mineral rhabdophane (hydrous phosphate of Ce and Y) from late Archaean palaeosols (ancient soils) remained as unoxidized trivalent Ce^{3+}, in contrast to the oxidized tetravalent Ce^{4+} in cerianite (CeO_2) in younger times[17].

Table 1. Oxygen gain–loss cycle in modern times (data from ref. 9)

Process	Reaction	Gain/loss
Photochemical reaction	Absorption of sun's UV rays splits water vapour–H_2O molecules releasing O_2 and O_3	Oxygen gain 10^8 kg/yr
Weathering	Oxygen reacts with iron in the rock to form iron oxides (rusting); carbon dioxide attacks minerals to form compounds	Oxygen loss 10^{11} kg/yr
Volcanism	Released carbon monoxide and sulphur compounds combine with O_2 in atmosphere	Oxygen loss 10^{11} kg/yr
	Water vapour released is photochemically dissociated to form O_2	Oxygen gain
Photosynthesis	Plants and bacteria use atmospheric CO_2 and release molecular O_2	Oxygen gain 10^{14} kg/yr
Respiration, decay	Bacterial decomposition of dead plants and animals consumes O_2	Oxygen loss 10^{14} kg/yr balanced by photosynthetic production
Burial	Rapid burial of dead organisms arrests oxygen consumption during decay	Oxygen gain
Recycling of sediments	Recycling of trapped C from ocean-floor sediments through plate tectonic dynamics, results in re-emergence of reduced C to the surface, a net source of CO_2 and a sink for atmospheric O_2	Oxygen loss
Fossil fuel combustion	Burning of oil, coal and natural gas	Oxygen loss 10^{12} kg/yr

Though many of the findings favour an O_2-poor Archaean atmosphere, results from a few investigations doubt this supposition. According to the new studies on pre-2.3 b.y.-old palaeosols, the much talked about ferric oxide precipitation during those times occurred by reductive dissociation of ferric hydroxide under an oxic atmosphere caused by organic acids generated from decay of organic matter[18]. Also, contrary to the views expressed by many, Fe^{2+} in sea-floor hydrothermal systems was mostly removed as sulphides rather than as the oxide Fe^{3+} and hence is unlikely to have used up the available oxygen[7]. Recent carbon isotope mass calculations in several 3.0–2.1 b.y.-old South African samples have, in fact, shown that the atmospheric O_2 was constant at a level comparable with Phanerozoic atmosphere[19]. Besides, studies assessing $\delta^{13}C$, reservoirs of O_2, Fe^{3+} and SO^{4-} in the crust and atmosphere have revealed that the progress of oxic conditions on earth, particularly during the Proterozoic, was episodic[20]. The view that an early Archaean oxygen-less atmosphere gave way to an oxic one during the Archaean–Proterozoic transition is now widely accepted. Quite a few associate this trend with the assembly of supercontinents by 2.2–2.0 b.y., when increased surface weathering, rifting and orogeny of the extensively exposed landmasses provided enough materials for the rapid burial of dead organisms on the land[5,14], thereby preventing oxygen-consuming sub-aerial decay[20–22]. However, carbon isotope record of sedimentary rocks[13,19], as well as calculations of net O_2 gain dispute this view[7].

Two mechanisms for the O_2 rise, one proposed about eight years ago[23] and another very recently[7], describe how plate tectonism was responsible for bringing about the change. In the former model, subduction of oceanic slabs is supposed to have mixed large amounts of ocean water, which could have gradually turned the mantle from reducing to oxidizing chemical state[11]. This would decrease the $H_2 : CO_2$ ratio in the volcanic gases and progressively arrest consumption of atmospheric oxygen[11]. Subduction of material rich in oxidized Fe^{3+} is also conceived to have brought about similar change in the upper mantle[24]. However, these models are disputed as data are not available supporting the efficacy of subduction processes or the oxygen-buffering capacity of the mantle or the redox state of ancient volcanic rocks[7].

The recently proposed second model is built on current ideas about the earth's interior emerging from application of new geophysical techniques to study the fate of the subducted crustal slabs, mantle dynamics and influence of the associated plume volcanism[25–32]. Recent seismic tomographic studies have imaged the subducted slabs piercing through the mantle layers and coming to rest at about 1600 km depth, which became virtually their 'graveyard' and an effective barrier, below which the mantle maintained pristine composition, while above it was depleted and heterogeneous[27,31]. This model satisfied some of the hotly-debated issues about mantle, such as the isotopic and heat flux anomalies and its layered structure. Called the 'upside down Archaean mantle hypothesis', this model speculates that the dense and oxidized slabs containing rich amounts of Fe^{3+}, resting close to the core–mantle boundary (CMB) created an upside down earth separating these oxidized material from reduced upper mantle. The combined heat arising from intrinsic radioactivity and from the hotter core below made this 'graveyard' zone at the base of the mantle buoyant enough around 2.7 b.y. ago, to trigger plumes of oxidized material to ascend to the upper mantle and feed mid-ocean ridge volcanoes. Gradually, by end of Archaean, the whole of the lower mantle region became so buoyant and unstable to overturn into the upper mantle. Thereafter, the outpourings and outgassing from such an overturned and oxidized mantle were no longer highly reducing, as in earlier times, and they were ineffective to soak up the atmospheric O_2. A gradual increase of O_2 in the atmosphere and reduction in the levels of CH_4, H_2 and CO followed, and this trend paved the way for the emergence of new forms of photosynthetic organisms, which augmented O_2 production further.

The authors of the new hypothesis have recognized at least two major overturn events, one at 2.74–2.66 b.y. ago and a second one at the Archaean–Proterozoic boundary 2.47–2.45 b.y. ago[7,33,34]. That such overturn events indeed manifested is supported by the oxidized nature of deep-mantle source rocks like komatiites and kimberlites as well as by the more oxidized, plume-generated large igneous provinces and flood basalts seen on several continents[34–36]. The authors contend that the interval between the two major plume events marked the rise of O_2 and notably the extensive deposition of BIFs. At the same time, the impacts of two major oxygen sinks became subordinate during the transition period. This happened because of the arrest of biogeochemical O_2 consumption rates in the wake of rapid burial of dead life and secondly, due to the decreased conversion of Fe^{2+} to Fe^{3+} by weathering of volcanic rocks, the latter rocks becoming negligible with progress of geological time. Collectively, all these processes led to the reduction of O_2 consumption levels below those of its production[4].

Oxygen revolution, undoubtedly, has generated considerable debate among geoscientists. Major uncertainties, as envisaged by the authors of the new model, stem from the nature of the Archaean tectonics and deep-mantle mixing within the period of hundreds of millions of years the subducted slabs are thought to remain at the CMB. The current debate has now swung to discussions about the roles of the few mechanisms involved in the rise, the answers for which will have to await the results from geochemical studies on samples representing different stages of mantle evolution. Needless to point out, geological transitions are not abrupt. They exhibit short-term swings or fluctuations before achieving semblance of stability, whether they concern unfolding of life or their extinction or the evolution of mantle or the core and this perhaps is the pattern about the rise of O_2 in the atmosphere.

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FROM THE ARCHIVES

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Problems of Road Research

At the second session of the Indian Road Congress held recently in Bangalore, the delegates, mostly Engineers from the different parts of India, discussed more than thirty papers dealing with the various aspects of their departmental problems. Apart from this professional interest in the construction and maintenance of proper roads, the provision of increasing facilities for vehicular and pedestrian traffic must always be of the utmost importance to the general public. The introduction of motors which has initiated new Engineering problems, must produce even a more profound effect upon the social and economic life of the people than the Railways did before, and the greater range and mobility of these mechanically driven vehicles have brought about a transformation in rural India and in the general methods of transport. The basic facts and the elementary governing considerations of road problems are of such vital character as to necessitate the creation of a Ministry of Transport and a Road Research Board financed by the Road Development Account. The need for a Road Research Organisation is evident from two factors, viz. the large amounts annually expended in India on the construction and upkeep of roads, and the large number of accidents associated with motor transport. The traffic problems are not confined to the technical and professional interests of the engineers alone, but they really belong to the domain of an applied science which includes not only Engineering but also Physiology, Psychology and Pedagogy. . . .

Generally speaking, the Indian roads are a standing menace to public health, acting, as they do, as the great carriers of infectious diseases. It is the common experience in all the Indian towns that the tarred roads during summer emit intense radiation of heat, parching up the air passages of nose and throat, which is a prelude to the onset of influenza and all other manifestations of bronchial and lung trouble. When the hot winds blow over such roads, carrying the dust particles and other impurities, the eyes and mouth of the users of the road become involuntarily filled with them. In using any new road binders the road engineers and the public health authorities have to cooperate and conduct experimental work before they are employed on a large scale. Roads have always acted as a source of danger to public health, and all attempts at improving its conditions must be supported by a definite knowledge of experimental investigations in the research laboratories.

The most frequent cause of road accidents arises from the skidding characteristics of the surface. We have at present no knowledge regarding the general influence of vehicle design on skidding, and formal investigation in this direction and in its relation to some conditions of road surfaces becoming slippery is desirable as a means of preventing those conditions from arising. Roads accumulate various types of debris on their surface, and behave differently under seasonal and atmospheric conditions and all these have to be linked with the texture and composition of binders. Another factor which produces road accidents is psychological. The statistical data of accidents have been collected in a more or less mechanical fashion, and few psychological tests have been devised to investigate the human factors in accidents. . . .

In such fields of enquiry the psychologists and doctors have to co-operate in the design of traffic and car signals, in the framing of traffic regulations, in the illumination of roads and vehicles and in the selection and rejection of drivers.

Clearly the pedestrian and the cyclist cannot be selected. They are in the habit of picking up their own methods of using the road, and since the traffic regulation is becoming scientific, arbitrary modes of using the road must always produce accidents. It is obvious that they, above all others, should be instructed how to avoid accidents from motor traffic. Instruction in schools and colleges and propaganda by private and aided agencies with a view to impart systematic training may produce the desired results. On the roads it is not uncommon to find the physically deformed and defective people, blind and deaf, old men and unsophisticated children sorely trying the patience of motor drivers, the motor cyclists and bicyclists. We have, on the other hand, villagers carrying head-loads, bullock carts carrying steel girders and bamboo poles, and beggars crossing from footpath to footpath, on sighting a car to stop. The Indian traffic conditions are peculiar, and their control and direction must be based partly on research work and partly upon the education and enforcement of traffic regulations.

The importance of scientifically prepared and accident-free roads in India must become evident when it is remembered that more than fifty per cent of her population uses the road bare-footed almost from infancy to old age, imbibing into the system the dust and pollution of the road accumulations. Will such an existence improve the physical efficiency of the people? It seems to us that the multiplicity of problems involved not only in the construction and maintenance of roads, but also in the reactions of such roads on public health, must be the chief argument in favour of instituting a Ministry of Transport and a Road Research Board.