on continents suggests that low-latitude wetlands were mainly responsible for these changes and that the role of high latitude wetlands became important after about 3 ky BP.

Much attention was paid to the signatures left by past climate changes in the form of distinct isotope ratios, reflecting the interplay of physical, chemical and biological processes. It was argued that global change research can make substantial progress through more systematic use of the isotope data. It was noted that a global network of monitoring stations is necessary to improve our estimates of sources and sinks of greenhouse gases.

Reports of computer simulations using orbital conditions for the period 6 ky BP showed enhanced seasonal cycle in the northern hemisphere, with a stronger African–Asian summer monsoon. These simulations indicate that changes in precipitation and temperature are large enough to influence distribution of vegetation. Vegetation sensitivity experiments indicate that northward expansion of grasslands in North Africa could have enhanced monsoon precipitation. The general conclusion from sensitivity experiments using various atmospheric general circulation models is that biogeophysical feedbacks substantially amplify the response of the coupled system to orbital forcing.

It was reported that a study of the lake records for 6 ky BP, point to a major expansion of the Afro-Asian monsoon. These studies also show that the climate of 6 ky BP was significantly different from today with respect to the regional water balance. Since 1992, there has been an international effort to establish a database of lake records or the record of how lakes have responded to changes in water balance as is seen in geological and bio-stratigraphical investigations of lake sediments. This effort is motivated by the possibility of using lake data as a record of past hydrological changes for climate model validation. The new global lake data set is a unique paleo-climate data resource containing records from nearly 700 sites worldwide.

The terrestrial biosphere has a central role in the climate and biogeochemical systems. The exchange of water, energy and carbon between land surfaces and the atmosphere drives many planetary scale processes. Many computer simulation models have been developed to understand global biospheric processes, and to evaluate their potential response to human activity. Results from all the three major classes of global terrestrial biosphere models—(1) atmospheric general circulation models, (2) equilibrium vegetation models and (3) terrestrial biogeochemical models, were discussed. Since it is difficult to address some of the complex issues using separate classes of models, it was emphasized from the experience of recent model comparisons, particularly the experience of Vegetation/Ecosystem Modelling and Analysis Project, that the requisite next step in model development is the creation of integrated dynamic ecosystem models.

Some of the presentations departed from the tradition of considering vegetation as an invariant aspect of general circulation models of climate and signified a reflection of the growing realization that vegetation is, indeed, an integral part of the climate system and that changes in vegetation structure and function can influence climate. It was reported that changes in climate as a consequence of vegetation behaviour do occur at comparable scales. The average influence of global terrestrial vegetation is small. Interestingly, in some regions such as the tropics, this can be of similar magnitude and even cause regional changes in opposition to the expected change in global average.

Records of atmospheric CO_2 concentration show that the global carbon cycle produces signals in the atmospheric CO_2 on several time scales. The seasonal cycle of atmospheric CO_2 in the northern hemisphere, which predominantly reflects changes in the growth and decay of terrestrial plants, exhibits varied amplitude and phase. The largest signals are associated with pulses of warming which peaked in 1981 and 1990. In the arctic, a biennial signal correlates with temperature.

Changes on short time scales were probably present in the past as well. There are, however, reasons to believe that some recent signals on these scales may point to an unusually rapid warming over the past 30 years, especially at high latitudes. It was argued that the presence of seasonal, biennial and decadal signals in atmospheric CO_2 linked to variations in climate parameters, offers a valuable testing ground for terrestrial carbon cycle models. It will be possible to do this successfully if the models can be forced by real time data rather than climatic averages. A special session on developing countries underscored the importance of tropical and sub-tropical regions in the study of global environmental change and noted that the success of global change research will depend on both expertise and data from all parts of the globe.

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COMMENTARY

India's manganese nodule mine site in the Central Indian Ocean

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Almost a decade and a half back, India had launched a massive exploration programme for manganese nodule deposits in the Central Indian Basin located 5 km below the ocean surface to achieve the goals of self-reliance in strategic metals like copper, nickel and cobalt. Even though little late compared to a few other countries like USA, Japan, erstwhile USSR, Germany and France to undertake this challenging venture, India achieved it in a short span of time (1980–1987), and our claim for a Mine Site Development in the Central Indian Basin (CIB) got registered with UNCLOS (United Nations Council for Laws of Seas) on 17 August 1987 (refs 1,2). After exploring nearly 4 million km^2, Indian scientists succeeded in demarcating two Pioneer Areas of 150,000 km^2 each having equal resource potential. Out of these two areas, one was allocated to the Government of India and the other one was reserved by the United Nations for the betterment of the humankind (demarcating two areas was an obligation on part of the pioneer nation towards the interest of other land-locked countries). As per the UNCLOS regulations, a Registered Pioneer Investor Nation (India was the first nation to register her rights in international waters!) has to relinquish nearly 50% of the allocated area within seven years of registration. In other words, India will have nearly 75,000 km^2 of mine site exclusively for her use. This area can be termed as First Generation Mine Site (FGMS). Our FGMS is located around 11°S latitude and 76°E longitude at a distance of about 2000 km from the southern tip of India.

Manganese nodules

The manganese nodules are accretion of inorganic colloidal Fe–Mn oxyhydroxides precipitated from ambient sea water or through diagenetic reactions within the sediment pore waters under fairly oxidizing environments. These nodules in general have a sub-spheroidal to spheroidal shape, are brownish black to black in colour, fine-grained and often amorphous. Less than a cm to 10 cm in diameter, some nodules form carpets over the seafloor sediment. The nodules generally have a density around 2 g/cm^3 and are supported below by less denser peneliquid sediment layer. This enigmatic positioning of the nodules on the sediment make them future potential resource.

In addition, to Mn and Fe (Mn = 18–34% and Fe = 5–15%) (ref. 3), the nodules carry significant amount of Cu, Ni and Co (up to 1.86%, 1.54% and 0.4% respectively)[3]. The abundance of nodules on the seafloor in the Indian FGMS is > 5 kg/m^2. High grade (Cu + Ni + Co) and more abundant nodule deposits generally occur at a water depth > 5000 m (below calcite compensation depth) in the CIB. Other forms of such deposits also occur on the seamounts like huge slabs called encrustations. Nodules accrete at an extremely slow rate (2–5 mm/million years) (refs 4,5) and hence may be considered as exhaustible resource.

Land resources of Cu, Ni and Co

Out of these three strategic metals, India produced during 1982–83 only Cu and her entire requirement of Ni and Co was met through imports. During the same period India imported 113 tonnes of Co worth Rs 3.2 crores and 10,600 tonnes of Ni worth Rs 47.5 crores[6] while during 1989–90 the Co import was around 182 tonnes worth Rs 7.8 crores[7]. India does not have any workable reserves of Co though the low-grade reserves are reported in Singhbhum district of Bihar. Hence, India has to depend upon the imports for Ni and Co, though a part of her requirement for Ni was met through domestic production during 1992–93. During this period we imported 5890 tonnes of Ni in various forms worth Rs 141 crores[7], an increase by a factor of 3 compared to 1982–83 in terms of monetary value.

As far as Cu is concerned, India has 100 million tonnes of measured and 214 million tonnes of indicated ore deposits. The copper-ore production went up from 7.5 lakh tonnes in 1972 to 52 lakh tonnes in 1992 valued at Rs 45 crores. Despite indigenous production India imported about Rs 10 crores worth Cu-ore concentrate during 1982–83 (ref. 6). The domestic consumption of combined Cu, Ni and Co was nearly Rs 105 crores during 1982–83, and during 1989–90 the domestic consumption increased almost 7 folds in terms of monetary value[6]. Based on the imported values during 1989–90, Co was priced around Rs 400 per kg, Ni was ~ Rs 200 per kg and Cu was priced in the London metal market at 1.5 £ per kg.

Mining technology

According to Glasby[8], the mining of deep-sea nodules can be a profitable business if a single mining vessel is capable of collecting 3 million tonnes of nodules per year on dry basis, i.e. ~ 4 million tonnes on wet basis since nodules contain about 25% of water. If this target has to be achieved, the yield of nodules per day should be around 13,000 tonnes considering 300 days per year operation and appears to be a difficult proposition. A more reasonable figure of 5000 tonnes per day per mining vessel was given by Padan[9] after studying various aspects involved in deep-seabed mining. With present day technology it may not be a difficult task to build a mining vessel or a platform to achieve this target. More critical components of the mining system are the nodule collector and nodule lifting systems. The Kennecott Consortium successfully tested a 7 tonne collector model in 1970s. During the same period Deep Sea Ventures Inc., Ocean Management Inc., Ocean Mining Associates and Ocean Mineral Company conducted system tests to achieve about 1000 tonnes per day[9]. With fast growing technology, there will be no difficulty in upgrading a mining system test from 1000 tonnes to 5000 tonnes per day yield, to meet the growing demand of the country.

Our manganese nodule reserves

As mentioned in the previous paragraphs, the FGMS will be of 75,000 km^2, which can be considered as the best piece with highest average abundance, highest average grade and easily accessible seafloor topography. Our FGMS falls in the siliceous ooze zone where nodule abundance averages to about 5 kg/m^2 and grade (Cu + Ni + Co) averages to 2.0% (ref. 3). Based on these observations, a rough resource estimate has been prepared, which shows that our FGMS contains Cu, Ni and Co reserve worth over Rs 100,000 crores!!

Economics

Once the worth of a reserve is known, the immediate question arises about the capital investment and returns. So far there has been no systematic effort done to understand the techno-economic assessment of nodule mining and metallurgy in the Indian context. Lenoble[10] for the time has carried out detailed economics considering the Pacific deposits and European and American economics and taxation system projected to 2010 AD. His estimates put the total capital investment on one set mining system, mine ore carriers and a metallurgical unit around 950 million US dollars, which at present exchange rate will be over Rs 3000 crores. This figure can be considered as valid for Indian conditions also. But the most important factors which vary are the maintenance, operation, labour etc. which need to be assessed totally under our domestic situations. What we require to make the nodule mining industry a profitable business are: i) demand (domestic as well as international) in excess to domestic support, ii) continuing increasing trend in metal prices, iii) an efficient mining vessel/platform with sturdy mining systems capable of operating throughout the year irrespective of weather conditions, iv) ore carriers to shuttle between mining vessel and a nearest Indian port, v) a metallurgical plant to handle/process over 5000 tonnes of nodules a day located at a nearest point to the mining area, most probably on the southernmost coast of Kerala, and vi) well-trained work force. Keeping these basic requirements for an efficient deep-sea nodule mining process, the efforts are needed to study techno-economic feasibility in the Indian context.

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Synthesis of cyclotriger*menes* – Carbon not alone in forming a three-membered unsaturated ring

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The so-called 'Double-bond rule' enunciated by Pitzer and Mulliken presaged that the second and subsequent row of elements in the periodic table will not be able to form stable compounds containing p_π–p_π multiple bonds among themselves or with the elements of the first row[1]. In line with this theoretical reasoning, multiple bonding was conspicuously absent in the chemistry of heavier Main Group elements until 1970's when the first stable phosphaimine, RP=NR′ and unconjugated phosphaalkenes, RP=CR′ ($OSiMe_3$) were isolated by Niecke[2] and Becker[3] respectively. Subsequent to these developments, there was sporadic interest in these types of compounds but the situation changed dramatically in 1981 with the isolation of stable double- and triple-bonded compounds featuring Si=C[4], Si=Si[5], P=P[6] and C≡P[7] functionalities. Since then there has been an explosive growth in the area of low-coordinated compounds of Group 14 and Group 15 elements, which continues to this day[8–15]. The stabilization of heavier Main Group element multiple bonds has been realized largely by using sterically demanding substituents which presumably exert 'thermodynamic control' over oligomerization and 'kinetic control' over other reactions to which a double or a triple bond is susceptible[16]. Using the same principle of 'steric stabilization', three-membered rings of heavier Group 14 elements such as $(R_2M)_3$ (R = Si, Ge or Sn) have also been synthesized[10,17]. However, unsaturated three-membered ring compounds of these elements akin to cycloprop*enes* are not known so far. Sekiguchi and coworkers[18] have now reported the first successful synthesis of cyclotrigerm*enes* bearing an unsaturated three-membered ring skeleton and their structural characterization by X-ray crystallography.

The strategy adopted for the synthesis of cyclotrigerm*enes* is shown in Figure 1. The final products 2*a* and 2*b* were obtained as dark red crystals (mp 157° and 178°C with decomposition, respectively) in low yields (20 and 13% respectively). The mechanism of formation of the unsaturated ring is obscure although the use of bulky silyl or germyl anions ($^tBu_3Si$ or $^tBu_3Ge$) is essential to generate the cyclotrigerm*ene* ring. When $GeCl_2 \cdot$ dioxane is treated with RLi (R = $C_6H_2{}^tBu_3$-2,4,6), only germylenes (GeClR and GeR_2) are formed; on the other hand, the reaction of $(Me_3Si)_3SiLi(THF)_3$ with $GeCl_2 \cdot$ dioxane gives the three-membered ring compound, $(R_2Si)_2GeR_2$ (R = $SiMe_3$) containing two silicon and a germanium in the ring skeleton.

The X-ray crystal structures of 2*a* and 2*b* reveal trigonal planar geometries around the two sp^2-hybridized germanium atoms with a Ge–Ge distance of 2.239(4) Å, which may be compared with the single bond Ge(1)–Ge(2) distance of 2.522(4)Å for 2*a* and 2.505(6) Å for 2*b*. These Ge–Ge distances in 2*a* and 2*b* and those observed in cyclogerm*anes*, $(R_2Ge)_n$ (n = 3,4 or 6) and digerm*enes*, $R_2Ge{=}GeR_2$ are listed in Table 1. The Ge–Ge single bond distance in cyclotrigerm*anes* is somewhat longer than those in the higher membered cyclogerm*anes* $(Ph_2Ge)_{4,6}$ while the Ge=Ge double bond distance in digerm*enes* lies in the range 2.21–2.35 Å. The Ge(sp^3)–Ge(sp^2) distance in 2*a* or 2*b* is intermediate between the Ge(sp^3)–Ge(sp^3) and Ge(sp^2)–Ge(sp^2) distances (Table 1).

The cyclotrigerm*enes* 2*a* and 2*b* do not undergo addition reaction with ethanol or diazomethane at room temperature. Al-