Some thoughts on Planetary Impact Structures in India and on the Importance of their Study

The recent occurrence of a devastating tsunami affecting parts of the coastal belt of India has diverted the attention of most geologists and made them suddenly active in formulating research projects on the subject of tsunami. Funding agencies also appear to be equally willing to support projects even remotely connected with tsunami, while studies of other natural disasters of greater significance remain neglected. One such subject which has not received enough attention is the study of effects of large body impacts of objects from outer space (*JGSI*, 2004, v.64, pp.97-107). In the case of tsunami the area of devastation is confined to coastal regions and if given previous timely warning there is at least a chance for people to move to higher ground and escape the ravages of the disaster. In the case of large body impact disasters, however, the result is total destruction. There is no way of protecting ourselves as land, ocean and even space become polluted and uninhabitable.

Earth A Much Bombarded Planet

The idea that the earth is subjected to a variety of impacts from time to time is not new. Planet earth, like other planets of the solar system, has passed through a stage of heavy bombardment. The scars left on the surface of the earth, however, are not easily recognisable because primary morphological features have been obliterated due to subsequent geological processes. The essential elements are however still preserved and can help in identification of such events through careful studies. So far, there are references to only three doubtful structures – Lonar in Maharashtra; Shiva crater of Bombay coast and Ramagarh structure in Rajasthan, but more detailed work has to be carried out to confirm their impact origin. According to Shoemaker, the well-known astronomer, "Earth resides in an asteroid swarm". Millions of pieces of rocks are flying past at staggering speeds and sometime these rocks hit us.

Those who have gone deeply into the subject say that while the majority of the impacts took place more than 4500 million years ago, in the last 2000 million years the rate of collisions appears to have remained stable but what is important is that such studies have revealed a certain periodicity in impact frequency. There are certain consequences of such impacts like widespread volcanism, sudden changes in sea level, magnetic reversals, mass extinction, presence of regional ejecta blankets and, more importantly abrupt world-wide changes in climate. Impacts, therefore, are the most violent of all natural disasters. In order to test astronomical theories geologists should be ready with their field data. Cometary impacts assume importance in correctly understanding the history of past events.

Areas to be Selected for Possible Study

The scare created by natural disasters has had, at least, one wholesome effect. It seems

to have suddenly woken up politicians and scientists in high places and made them agree to large-scale funding for research. It has happened in the case of recent tsunami and it is felt that present is the time for forcing the pace of research on identification of past climatic changes and the possibility of such changes taking place more frequently as a result of the impact of asteroids, meteorites and comets.

A re-examination of the regions where major breaks in the past geological record have occurred appears desirable. Do we have a database of the full list of species and animals identified so far in India from the commencement of geological record up to the present? Is there any recognizable periodicity in their extinction? Are we in a position to prove that abrupt extinctions are linked with changes in climatic record, such as global warming or reduction in temperature leading to prolonged droughts or glaciation? A close inspection of the Indian fossil record with such an object in view is desirable. Similar study at Berkeley, California, has indicated that mass extinctions have taken place regularly every 62 million years! (*Nature*, 10 March, 2005, p.208). Can similar studies be attempted based on Indian fossil record?

An increase in galactic activity, it is stated, might set off 'a highly destructive comet shower' that would drive mass extinctions on earth. Hindu mythology, which extends thousands of years backwards in time, repeatedly refers to *pralaya* (catastrophic destruction) which overwhelms the earth periodically, exterminating all vestiges of life on the planet. The one described in *Skanda Purāna* of the birth of *Kārtikeya* (constellation of Pleides) and his fall on earth as Skanda is reminiscent of a past impact event. Impacts, therefore, are not uncommon in human history and thus require a detailed study from all aspects. The classic description of such catastrophic events in our ancient literature should be considered as 'our ancestors warnings to their descendants about the potential calamity from the sky' and provide the necessary initiative to take up such studies. Shoemaker has predicted an impact frequency of a body of the size of Tungaska bolide as frequent as one in 1500 years. Larger impacts by asteroids 100 km in size are considered to have caused the Jurassic, Cretaceous and Permian extinctions, with a frequency of one in 50 to 100 m.y. The largest meteorite crater discovered in recent years is that of Popigai in Siberia, the structure measuring 95-100 km in diameter.

Multi-disciplinary studies aimed at gathering evidences of shock metamorphism, present day geomorphic expression of the original crater morphology and geophysical characteristics should be attempted. The presence of original projectile meteoritic material in terms of unusual trace element geochemistry and isotopic signatures are necessary. Our petrologists too should get better oriented in recognizing shock metamorphism effects. Reference material from clearly known structures from elsewhere should be accessible for comparative studies.

The description of a meteor crater formed by low velocity crater 1.2 km in diameter appearing in *Nature*, 10 March 2005, p.157 is interesting because of its close similarity to Lonar Crater from India.

Glikson and others (*EPSL*, 2004, v.221, p.383) have described impact fall out units, spherule-bearing pebble to cobble size chert impact conglomerate from greenstone belts of Pilbara craton. Greenstone belts of Karnataka show several bands of spherulite conglomerate

which require re-study. Greenstone belts are likely to bring out clear-cut examples of impact generated structures. All volcanic agglomerates and breccia need a re-look for the identification of quench structures, melt droplets, and remnants of melted glass. These products have to be examined for their geochemical signatures. Evidence of large impact structures are being recorded in many Archaean schist belts.

There is no dearth of problems in this frontier line of research which only geologists can carry out. Careful outcrop by outcrop study aided by pictures presented by remote sensing satellites, identification of unusual rock types, especially tektite fields, detailed petrographic study of samples for the presence of shocked quartz, striped olivine, nickel-bearing spinels and nano-sized particles of microdiamond and identification of high temperature polymorphs like stishovite, coesite, maskalynite etc. – all such evidences may cumulatively lead to impact recognition. Identification of the frequency of such material in the geological record could provide the lead to prediction, and warning of the consequences, of such disasters.

Palaeoclimatic reconstruction of the past, extending backwards in time to at least Mid Holocene (5000 years ago), is a field of study which should no longer be neglected. This will involve a close study of deltaic sediments along the coastline, lake sediments and tree-rings. The latest technologies available should be utilised in interpreting the data to support changes in climate which were either abrupt or gradual and persisting over longer periods. Two intervals are stated to be significant in the past 2000 years – the Medieval warm period (1200-1400 AD) and the little Ice Age (1600-1850 AD). Can such things happen in the future? What about the causes and frequency of their occurrence? Claube and Napier (1990, the *Cosmic Winter*) ask 'to what extent is our mastery over nature during the past 5000 years an illusion, a mere quick spell before some uncontrollable spell overwhelms us'?

Periodicity of Impacts

The frequency of potential future impacts from the sky are being estimated from the observations of the orbits of earth-crossing asteroids and short-lived comets. NASA has a programme for surveying such objects which have a tendency to come too close to the earth and devising nuclear missiles to break them into smaller pieces or change their course in some subtle ways. 'Space Guard Survey', designed to detect the orbit of objects which may prove to be hazardous to mankind, has been initiated. While such studies are presently beyond our capability, geologists can at least direct their attention to a study of the past geological records, which are replete with repeated cycles of volcanism, breaks in climatic record and mass extinction, and try to record their frequency.

The identification of impact craters in several parts of the world in recent years indicates that large-scale impacts have occurred before and will continue to occur in future and their frequency is a cause of alarm affecting the future of mankind.

The geological record clearly testifies that it is punctuated by catastrophic events which have to be carefully studied. At least four major periods of mass extinction have been recognised at around 439, 364, 250 and 65 million years ago when nearly 95 percent of

plant and animal species appear to have been exterminated. It is thus permissible to equate the mass extinctions with extra-terrestrial impacts which had the effect of destroying everything and making the earth uninhabitable.

Asteroids are stars in orbit and when one breaches the atmosphere is termed as meteorite. A shooting star is one which travels at high speed but is of small size. They violently explode when they strike the atmosphere. Even the smallest asteroid is known to be rich in minerals containing $1 trillion worth of nickel, $8 billion worth of iron and $700 billion worth of platinum?. This gives an idea of their metal potential.

Our ancient classics are replete with references to comets (*ketu*) with tails which suddenly appear orbiting for months and causing great panic among people but not much interest has been given to the study of these cometary objects. Cometary impacts appear to be, probably, the major cause of past mass extinction, by raining fire and filling the earth with clouds of dust and blocking sunshine altogether for years on end which could also have resulted in abrupt climatic changes leading to extermination of species.

Life on earth seems to have not only survived these catastrophic events but, what is even more astonishing, has given rise to newer and more evolved forms. This extraordinary power seems to indicate that life itself may not be a purely terrestrial phenomenon but a part of the cosmic universe. These visitors from heaven, therefore, seem to have the ability not only to create, but also to destroy and recreate!

New isotopic studies indicate (*Nature*, Jan.2005, p.26) that the outer layer of the earth has grown largely through material added by impacts from planetissimals and that there is not much exchange between the deep mantle (as represented by ocean island basalts) and the ocean ridge basalts (magma generated by convecting upper mantle). Isotopic composition of water too seems to indicate an extraterrestrial origin as against degassing through the earth's interior (*Science*, 2001, p.1056). These are important new developments which emphasise the significant role played by impacts in building the outer layers of the earth.

Cometary Record on Earth

References to celestial objects, especially comets, in our ancient classics are fairly frequent. R.N. Iyengar has recently presented a useful summary of records of cometary observations in ancient India (*JGSI*, v.65, 2005, pp.663-665). He has gathered information from *Rig Veda*, *Puranas*, Chronicles of Moghul period (18-12 centuries ago) and right up to the present, including that of Hailey's comet. Not only did the ancient seers observe a periodicity in their appearance but gave them appropriate names *Chala ketu*, *Dhuma ketu*, *Karāla ketu*, *Sammārjinī Mahāketu* (broomstick great comet).

More interestingly, Iyengar refers to the blanketing of the sun's rays by dark dust. These observations, often expressed in poetic language, refer to an extended record of cometary and meteoritic activity spread over a long period. They are some of the earliest records in literature. It is fortunate that our Indian ancestors were careful observers and could express themselves in verses of great beauty which have survived even to this day.

Comets are made up of water in the form of ice and frozen carbon dioxide and countless numbers must have bombarded the earth in its early history. The Precambrian geological

record is full of layers of carbonaceous shales and graphitic schists. Could they be the products of cometary dust enveloping the earth during those remote periods? The geochemistry of carbon assumes importance. According to Claube et al. (1996, *Astrophysics and Space Sciences*, v.245, p.43) giant comets thrown into short period earth-crossing orbits are a major source of flux into the inner planetary system. Comets in chaotic orbits >100 km in diameter probably constitute a major hazard than stray asteroids. Iyengar feels that comets were more frequent in the visible sky in ancient times than they are now, for it is possible, he feels, that down from 4th millennium BC Indian mythology is enriched with celestial happenings including earthquakes and disasters on ground.

The most recent (74,000 years old) instance of cratering and large-scale dispersion of ash ejecta is that from Toba, a large lake 100 km long, 30 km wide and 450 m depth depression in northern Sumatra which is estimated to have ejected into space 7×10^{15} kg (equal to 2800 km^3) dense rhyolites. Clouds of ash have drifted over a greater part of the Indian ocean and deposited a 12 cm thick bed of ash in the Bay of Bengal. What triggered this explosion and generated such a cloud of dust is a matter of conjecture but whatever the origin, it indicates the incidence of an extended winter for six years. The possibility of similar occurrences within the next thousand years cannot be ruled out, justifying the need for an intensive study of impact induced climatic changes and the disastrous effects on life.

Impact Structures and Mineralization

Vredfort dome, Southwest of Johannesburg in South Africa, the largest producer of gold, is now accepted as a deeply eroded impact structure of Paleoproterozoic age whose estimated original diameter was probably 300 km. The noted Sudbury structure in Canada with its high concentration of nickel is another example. In Popigai, Siberia, a well preserved giant impact structure considered as the world's geological heritage containing the largest concentration of diamonds so far known has come to light. The exceptional concentration of economic minerals in these structures raises the question whether such abnormal concentrations could be the result of extra-terrestrial impact. The older geologists of Mysore (now Karnataka) were obsessed with a mylonitic gneiss which they labelled as *'Champion gneiss'* associating it with the Champion lode which produced 800 tonnes of gold and made the Kolar Gold Field, a giant gold field. The quartz veins which contained gold were of an exceptionally blue colour, the result of intense microbrecciation.

Does the Champion gneiss have an extra-terrestrial impact history: It is strange, but nevertheless true, that quite a few of the impact structures have proved to be immense sources of gold, nickel, uranium and hydrocarbons.

The study of meteoritic and cometary impacts on earth is a recent development and such studies in India have not even been initiated. Astronomers have identified falling foreign bodies, ranging in size from a few metres up to 200 km across, and ranging in age from Reçent to Precambrian in different pats of the world. It should not be assumed that we were immune to such natural disasters. In a meeting organised jointly by the Royal Astronomical Society, the British Planetary Society and the Geological Society in Dec. 1998, for defining the effects of sub-critical cosmic impacts on the earth, evidences were

produced for an extra-terrestrial catastrophic impact in the Middle East during the second half of the third millennium BC. Tanguska meteorite fall in North Siberia on Jan.30, 1908 with the meteorite believed to have exploded 7 km above the earth surface and the blast severely affected an area of 2000 km^2. If it had happened in a populated area like India, the disaster would have demonstrated clearly the destructive power of such a hit. Deccan basalts covering an area of 500, 000 km^2 were also probably initially triggered by a major asteroid impact.

The question may be asked: Are these impacts frequent and whether they should be taken seriously. The Oxford Companion to Earth (2000) estimates the probability of an individual being killed as a result of a really minor impact event to be the same as that of being killed in a commercial flying accident, i.e., 1 in 20,000. The danger therefore, is real and cannot be ignored.

Conclusion

Readers, I hope, will not fail to realise the importance of taking a relook at our older geological maps and initiate field studies wherever called for in view of the wide ranging implications of such studies on human welfare.

I would like to draw particular attention to a re-examination of (1) the oval-shaped Cuddapah Basin with its characteristic structure and associated uranium and barium mineralisation and the distribution of diamond-bearing kimberlite pipes allround (Krishna Bramham in 1984 had suggested the possible impact origin of the Papaghni basin); (2) the volcanic group of islands off the coast of Bombay, the islands of Saurashtra and Kachchh, seismically highly active with unusual rings, troughs and central uplifts showing good hydrocarbon potential; (3) the region of Malani rhyolites, an exceptional concentration of acid igneous rocks; (4) the Simlipal Complex and associated Cu-Ni mineralisation – keeping the impact model in view. Detailed sedimentological and isotopic studies of the coastal shelf sediments, aided by all the tools available of isotope geochemistry, should enable us to construct the chronology of climatic changes during the past 5000 years with the possible identification of impact generated tsunami.

Study of the human past, a subject long neglected by geologists, is a necessary requirement for a better understanding of the future. It provides a rich database from which one can hope to learn a great deal.

It is easy do dismiss the above facts as pessimistic speculations. We should not forget that 'Dangers which are conceivable as possible are also possible in practice'.

9 April, 2005 B.P. RADHAKRISHNA