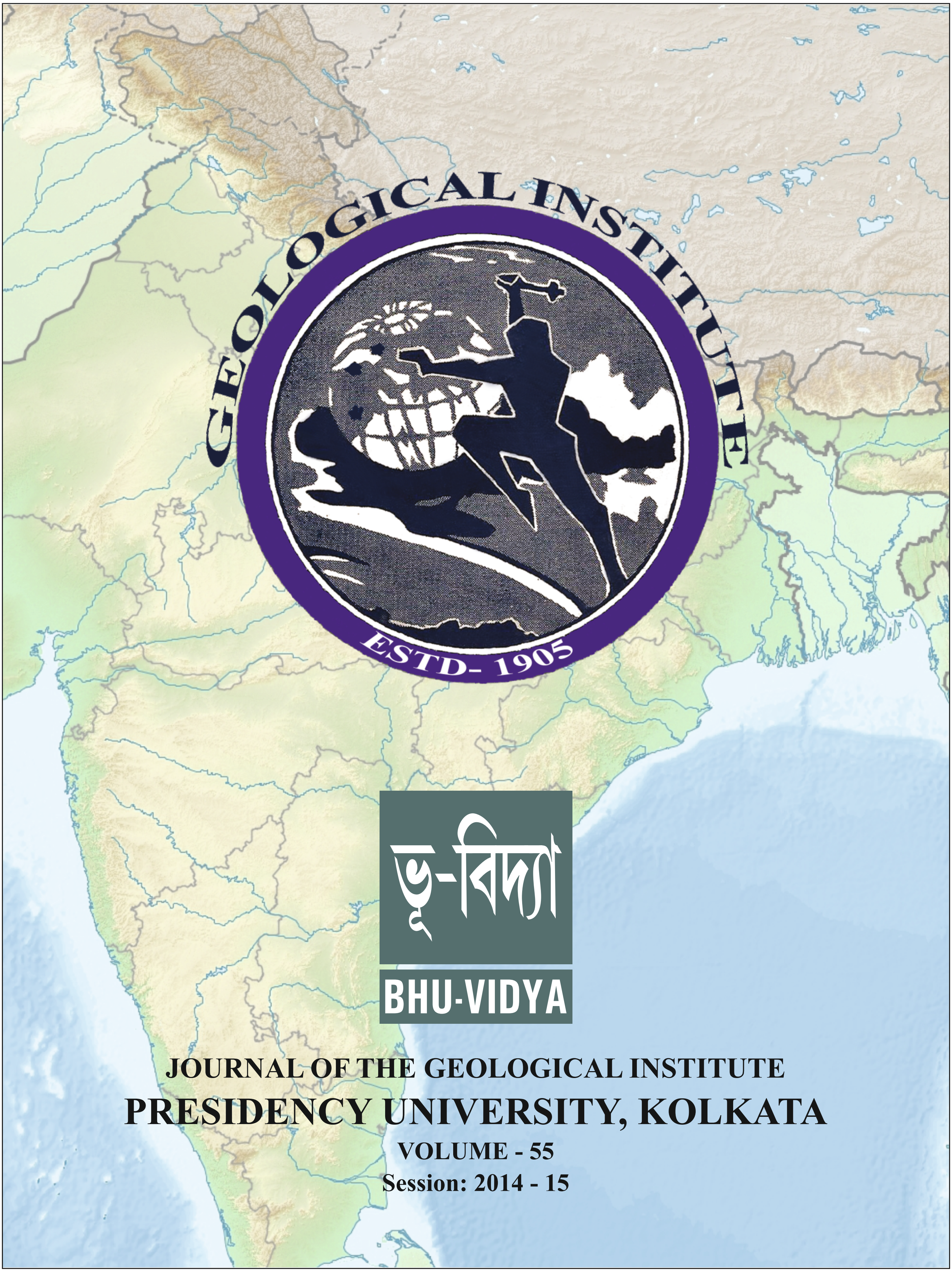

GEOLOGICAL INSTITUTE

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BHU-VIDYA

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PRESIDENCY UNIVERSITY, KOLKATA

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Presidency University, Kolkata

Editor
Hindol Ghatak

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Foreword

The 55th volume of Bhuvidya this year is published today with contributions mainly from students. We are happy to be able to maintain this tradition and the century-old practice. The Geological Institute organized different academic activities this year. Eminent scholars and researchers from different parts of the country and abroad delivered talks during this year. Students also participated in several national events organized by other universities and institutes. The Department had organized a National Seminar on 'Making of the Indian Continent'. The seminar provided the students a platform for interaction with scholars from all over the country. The Department has a plan to organize a series of national seminars in coming years keeping in mind the 125th Anniversary in the year 2016. An active support from our alumni will be a great help in promoting such objectives and activities of the Geological Institute in coming days.

Joydip Mukhopadhyay
President
Geological Institute

22nd December 2014

Editorial

On behalf of the Geological Institute we, the students of Department of Geology of Presidency University, are immensely pleasured and honoured to bring out the 55^{th} Volume of Bhu-Vidya.

As previous years, even this academic year the Geological Institute was involved in organizing various lectures and seminars related to Geology. This has been a tradition for years, to intrigue the interest and rejuvenate the broader and wider aspects of Geo Science among the students. The safeguarding of this very ideology has been tried to the utmost while it gets reflected in the form of this edition of Bhu-Vidya, the Journal of Geological Institute.

We extend our sincere gratitude to the present and ex students, our respectful and beloved Professors and all other well wishers for their continual support in making the venture a success.

We earnestly wish that in future, the upcoming committees will overcome the drawbacks we left. A prior sincere felicitation and motivation for their aspirations.

27^{th} September, 2014 Hindol Ghatak

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Bhuvidya

CONTENTS

CORAL REEFS AND ITS IMPORTANCE IN GEOLOGY

Sagarika Samaddar, *B.Sc 2nd Year*

Geologists define reefs and related terms for example bioherm, biostrome, carbonate mound using the factors of depositional relief, internal structure and biotic composition. There is no consensus on one universally applicable definition. A useful definition distinguishes reefs from mounds as follows. Both are considered to be varieties of organosedimentary buildups: sedimentary features built by the interaction of organisms and their environment that have synoptic relief and whose biotic composition differs from that found on and beneath the surrounding sea floor. Reefs are held up by a macroscopic skeletal framework. Coral reefs are an excellent example of this kind. Corals and calcareous algae grow on top of one another and form a three-dimensional framework that is modified in various ways by other organisms and inorganic processes. By contrast, mounds lack a macroscopic skeletal framework. Mounds are built by microorganisms or by organisms that dont grow a skeletal framework. A microbial mound might be built exclusively or primarily by cyanobacteria. Excellent examples of biostromes formed by cyanobacteria occur in the Great Salt Lake of Utah and in Shark Bay, Western Australia.

Modern reefs are a focal point for study by varied groups of researchers each of which has its own perspectives and priorities. Marine geologists study relatively young less than 10000 years reef structures that have formed since the latest glaciation. Stratigraphers often focus on the three-dimensional nature of features developed over much longer periods of time and often built during multiple episodes of sea level rise and fall. The U.S Geological Survey(USGS) working closely with academic institutions, state and other Federal agencies is spearheading an effort to better understand the oceanographic and geologic controls on the structure and processes of their nation's coral reef ecosystems. They aim to identify innovative mapping methodologies to find the most efficient methods of mapping and remote sensing that can be used to address coral reef issues of distribution, morphology, benthic cover and history of existing U.S coral reef systems in the Pacific basin. The approach to these efforts relies on a combination of field measurements and laboratory studies in order to characterize coral reef habitats. USGS uses a wide range of tools including in-water observations made by scuba-divers, high-resolution bathymetry from airborne LIDAR (light detecting and ranging), air-borne and space-based multispectral remote sensing imagery, underwater towed digital photo/video mapping systems and swath acoustic seabed mapping systems.

The Proterozoic Belt Supergroup contains evidence of possible microbial mat and dome structures similar to stromatolite reef complexes. Archeocyathids are the first reef building organisms from the Poleta formation in the Death Valley area. Ancient reefs buried within stratigraphic sections are of considerable interest to geologists because they provide paleo-environmental information about the location in Earth's history. In addition, reef structures within a sequence of sedimantary rocks provide a discontinuity which may serveas a trap or conduit for fossil fuels or mineralizing fluids to form petroleum or ore deposits. Octocorals are rarely found as fossils as they lack a hard skeleton but many paleontologists believe that one of Britain's oldest known animals Charnia belongs to this group. Faint impressions of this soft-bodied animal have been found in late Precambrian rocks of Central England and southern Wales.

Corals including some major extinct groups Rugosa and Tabulata have been important reef builders through much of the Phanerozoic since the Ordovician period. However other organism groups such as calcifying algae especially members of the red algae Rhodophyta and molluscs especially the Rudist bivalves during the Createceous period have created massive structures at various times. Duting the Cambrian period the conical or tubular skeletons of Archaeocyatha an extinct group of uncertain affinities possibly sponges built reefs. Other groups such as the Bryozoa have been important interstitial organisms living between the framework builders. The corals which build reefs today, the Scelaractinia arose after the Permian-Triassic extinction event that wiped out the earlier rugose corals and became increasingly important reef builders throughout the Mesozoic Era. They may have risen from a rugose coral ancestor. Rugose corals built their skeletons of calcite and have a different symmetry from that of the scelaractinian corals whose skeletons are aragonite. However there are some unusual examples of well preserved aragonitic rugose corals in the late Permian. In addition calcite has been reported in the initial post-larval calcification in a few scelaractinian corals which arose in the middle Triassic may have arisen from a non-calcifying ancestor independent if the rugosan corals which disappeared in the late Permian.

Can Climate Change Fuel Volcanic Eruptions?

Subhasish Debnath, *B.Sc 3rd Year*

Well, we all know that volcanism can dramatically alter the climate, often in cataclysmic ways. Volcanic eruptions are responsible for releasing molten rock, or lava, from deep within the Earth, forming new rock on the Earth's surface. The gases and dust particles thrown into the atmosphere during volcanic eruptions have influences on climate. But what about climate's effect on the behaviour of volcanic eruptions? Does the rock hold evidence that climate changes have, over time, caused a surge of volcanic eruptions?

Fascinating, and not new. Geologists have speculated for decades that past periods of warming, through the melting of glaciers, might have propelled a newly eruptive era. The fact can be understood as a matter of pressure relief: Taking that icy load off the land may make it easier for magma to surge out. In some situations, it might even cause even more melting. If you remove a large ice sheet, then the amount of work required to crack that rock suddenly becomes a lot less.

But there is a problem: eruption records get spotty as you move back in time. It's likely that only 1 percent of actual eruptions are captured in the scientific record.

Geologists at Harvard University published an influential paper, in 2009, charting a rise in volcanic activity two to six times above background levels, beginning 12,000 years ago. Eruptions, they argued, track the wax and wane of the ice ages. It was a provocative hypothesis, and it might be true, but it lacked much empirical evidence that the melting of an ice sheet had caused more eruptions in most of the world's volcanoes.

Such evidence does exist in one spot: Iceland. There's a solid chemical and stratigraphic record showing that the island experienced a volcanic surge after its ice sheet retreated. But Iceland is a geological freak, its volcanism driven by a hot spot and the rifting of tectonic plates. Ninety percent of the world's volcanoes do not resemble those of Iceland; they are instead found at subduction zones, where one plate slides under another.

But a recent study by geologists at oceans off South and Central America, shows that climate change could fuel volcanic eruptions. According to the study, the rapid rise in sea levels could cause a dramatic increase in volcanic eruptions. The study, published in the journal Geology, found that during periods of rapid climate change over the last million years, the rapid melting of continental glaciers and the resulting sea-level rise eventually increased volcanic eruptions. Every so often, shifts in Earth's orbit lead to rapid warming of the planet, massive melting of glaciers and a quick rise in sea levels. According to the researchers, when glaciers melt, they reduce the pressure on continents, while sea-level rise increases pressures on the ocean floor crust. The change in pressures on the Earth's crust seem to cause increases in volcanism. In general, the speed of the transition from ice age to melting, rather than the total amount of melting, predicted how intensely the volcanic eruptions increased.

The study doesn't address whether modern-day climate change would have any impact on the frequency of volcanic eruptions, though in theory it's possible. But even if anthropogenic, or human-caused, climate change impacts volcanic eruptions, people wouldn't see the effect in this lifetime, because the volcanic activity doesn't occur immediately after the climate change.

Lunar Anorthosite And Its Terrestrial Analog In India

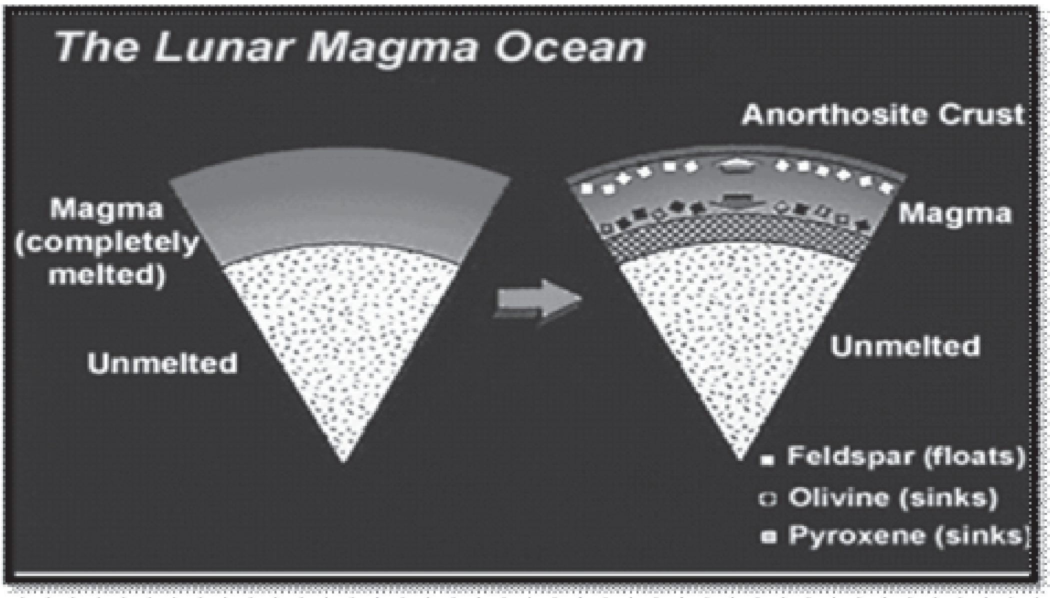
Shreyasi Das, *B.Sc 3rd year*

INTRODUCTION:

Anorthosite is a phaneritic, plutonic rock characterized by a predominance of calcic plagioclase (>90%) and a minimal mafic component (Pyroxene, olivine, ilmenite, magnetite etc).

With the utilization of telescopic near-infrared spectra and multispectral images of the Moon provided by the Galileo and Clementine missions, Anorthosites have now been identified from beneath a shallow near-surface layer of pure anorthosite unit. These anorthosites termed as Lunar anorthosites are quite fine-grained (only very few crystals are larger than 1 cm) with very high Ca/Na ratios. They contain about >90% calcium rich plagioclase (An content>70) as well as minor amount of pyroxene and olivine, which are relatively iron-rich. They have high Al_2O_3 content with low Mg and Na/(Na+Ca) and low incompatible lithopiles (Th,La).

The distribution and modes of occurrence of lunar anorthosites clearly indicate that a thick, global layer of anorthosite is present at various depths beneath most portions of the lunar surface. It has been thought that the lunar highland crust was formed by the crystallization and floatation of plagioclase from a global magma ocean although the actual generation



mechanisms are still debated. The composition of the lunar highland crust is therefore important for understanding the formation of such a magma ocean and the subsequent evolution of the Moon.

LUNAR MAGMA OCEAN HYPOTHESIS:

The magma ocean hypothesis was proposed on the basis of numerous analyses of lunar samples of ferroan anorthosite (plagioclase-rich rock with minor amounts of mafic silicates that have a relatively high Fe/Mg ratio) collected from a small portion of the nearside highland regions. It states the anorthosite layer in the upper portion of the primordial crust is produced by plagioclase flotation in the global magma ocean. During the formation of the Moon through accretion of materials ejected from the proto-Earth after impact with a Mars-sized body, the heat of accretion resulted in the formation of a lunar magma ocean (hundreds of kms in depth).This magma ocean cooled to produce a variety of cumulate rocks .Early formed cumulates crystallized at high temperature and pressure and are rich in olivine and pyroxene, whereas cumulates that formed later are rich in plagioclase which floated on the magma ocean to form the earliest lunar crust, with ferroan anorthosites (FANs) representing the primary rock type of these cumulates. Efforts to determine the age of the Moon is based extensively on the chronology of these cumulates.

TERRESTRIAL ANALOGS IN INDIA:

Rocks similar to lunar anorthosites are available on terrestrial surface, which could provide vital clue about origin and evolution of the Moon. Several works have been conducted on a number of anorthosite complexes in southern peninsular India considered as equivalent of lunar analogs in terms of chemistry and mineralogy. The anorthositic body located in various parts of Southern peninsular namely Sittampundi complex, Oddanchatram anorthosite complex,Kadavur anorthosite, Chimalpahad anorthosite Complex (CAC), Kondapalli layered Complex (KLC) were studied and compared. While comparing the chemistry of five terrestrial anorthosites of Southern peninsular India with the lunar highland geochemistry, the chemistry of Sittampundi anorthosite is found almost equivalent of lunar anorthosites.

Layered complex of anorthositic and gabbroic rocks (SAC) are located at Sittampundi, Namakkal district, Tamil Nadu, India. The Sm–Nd isotope studies of Sittampundi anorthosite complex had given an age of 2935±60 Ma indicating Archean period. The Archean anorthosites (> 2.6 Ga) are primarily of interest because of their closer chemical similarity to highland anorthosites on the moon. Anbazhagan and Arivazhagan (2010) have revealed that Sittampundi anorthosite is chemically and mineralogically equivalent of lunar anorthosite attributing 73% of plagioclase with An>67% and nearly 14-15% of pyroxene along with 5% of olivine.

The content of clinopyroxene in lunar highland is ~3-14%, and in the terrestrial analog it falls from 0.35-14%.The lunar highland orthopyroxene

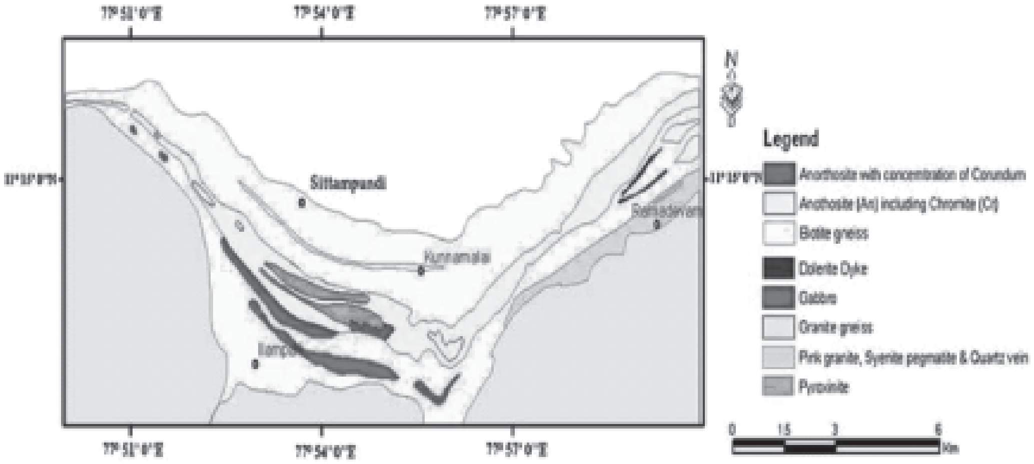


Fig. 2 Geology of Sittampundi Anorthosite Complex (after GSI 2005)

accounts up to 32%whereas the terrestrial orthopyroxene is restricted to 8%. Orthoclase and quartz are present in CAC, however those are absent in Lunar anorthosites which is supporting the non-completion of differentiation of lunar magma. Though lunar anorthosites are characterized by absence of amphibole and garnet, the Sittampundi anorthosite complex, analog test site for lunar highland region in terms of chemistry and mineralogy, contains small amounts of hydrated minerals, due to alteration of the pyroxene and/or olivine. The terrestrial analogs may vary from genuine lunar soils in several aspects, mostly due to the effects of micrometeorites and solar wind on the moon. Analyses of Apollo 11 samples show the anorthosites are deficient in alkalis and phosphorus due to volatilization on the surface. However, the terrestrial analogs have higher alkali contents.

CONCLUSION:

Samples of actual lunar regolith are limited which makes development of lunar analogs necessary to replicate the physical, chemical, mineralogical and geotechnical properties of lunar soil for Earth based studies. Planetary scientists are using terrestrial analogs for various kinds of research and comparative studies between terrestrial and planets. Repeated analog studies are required to understand physical, chemical and spectral properties of lunar rocks.The image analysis and spectral comparison of the lunar analog sites are useful for remote sensing study of lunar highland region. This type of study is of great significance in the context of ISRO's initiatives to send series of missions to the moon for selenological exploration.

Concept of Remote Sensing and it's scope

Pritam Kumar Ghosh, Subham Chatterjee, *B.Sc 2nd year*

Introduction:

Remote sensing is the acquisition of information about an object without physical contact. Any type of studies of earth such as survey, analysis, terrain, study have now become more easy by recent developments and principles of remote sensing. Earlier any type of survey was made in a conventional way; that, one has to go personally to the field and to do the work on the basis of information collected. But with the availability of aerial photographs and Satellite Imagery the geological studies have become easier. In case of Remote Sensing Technique one can get information of inaccessible areas and maps can also be drawn in the laboratory. Visual images of large areas enable the observer to perceive relation between objects and their environmental surroundings which to a ground observer might not be evident. The photo and imagery interpreter can study significant pattern without the distraction of irrelevant details and can compare these patterns with map representation. It is also important that every detail or element can be studied clearly under different instruments like pocket stereoscope, mirror stereoscope, Multispectral Digital Analysis System (MDAS) etc. Aerial photographs are used since 1914 and from 1972 Landsat Imagery gives an additional tool. Landsat Imagery is now considered a powerful tool in geographical research as it provides more synoptic coverage giving better knowledge of larger areas. From aerial photographs and Satellite Imagery, a new science has been developed known as 'Interpretation Science.' This science is recently developed and from this details of terrains can be worked out.

Advantage of Remote Sensing Technique

There are certain advantages also of using Remote Sensing Technology over conventional survey. The use of air-photographs for soil survey is in fact comparable to the use which any soil surveyor makes of the correlative indication in the field. The air-photo however has in this respect some very definite advantage.

(1) First of all it is possible using air-photos to analyse systematically the whole area to be surveyed.

(2) Secondly without going to a hill, rugged terrain or in a dense jungle the researcher can prepare a preliminary map with sufficient accuracy.

(3) The whole area to be covered can be viewed at a time and plan could be made accordingly.

(4) The possibility of planning the field

work can be done in the area. It can be chalked out in advance taking care of the indication of the physiography that has been studied with the help of air-photos and Imagery.

Scope of the Work

The photo-geographers usually rely on air photographs and satellite Imageries in tackling geological analyses. In this dissertation the researcher has based his observation solely on air photographs and some collateral information have however been incorporated here to magnify the subject. According to American Geographers there are three principal reasons of their reliance on aerial photography and Satellite Imagery than their colleagues in other sciences. The three reasons are:

(1) There are some geologists, whose training predates the development of photo-geographic methodology, they are unacquainted, with the extent of aerial photographic coverage, how to obtain photography of regions of interest, or how to interpret the photograph once obtained. This type generally belongs those associated with Indian Universities;

(2) The photo-geographers work is unusually complex. He may be well acquainted with all images relating to his own field of interest. But since geography deals with all phenomena on the earth's surface theoretically he should also be able to identify and interpret almost every image on any photograph. He must be selective in choosing the images for his requirement. The object of this study at first in confined to study the Landform along with underground geology.

(3) The third is the most important. The work of geologists is more often institutionally sponsored than commercially demanded.

After step by step of critical studies, viz., recognition and identification, analysis, deduction, classification of the desired subject in either landform or landuse, structure, relief etc. and after full establishment of their identity, we bring out conviction and prepare maps and description of the area through research.

Impact Crater

Subham Sarkar, *M.Sc 1st year*

1. Introduction

A full moon is the source of many tales and imaginations, and who knows how many poetries. Do you remember that old lady of the Moon, or that rabbit from your childhood? Some also imagine it to be a face.

The basis of these ideas originate as the surface of the Moon is ornamented with big and small craters.

The space around the internal planets is not entirely “clean”; it rather contains a lot of planetary debris, as the *asteroids*. The asteroids range in size from as small as a pea nut to a few hundreds of kilometres in diameter. These celestial bodies come into the gravitational field of larger planetary bodies and get caught up into an orbit around it and ultimately collide with the bodies finally making an Impact Crater. This article discusses the dynamics and kinematics of this phenomenon.

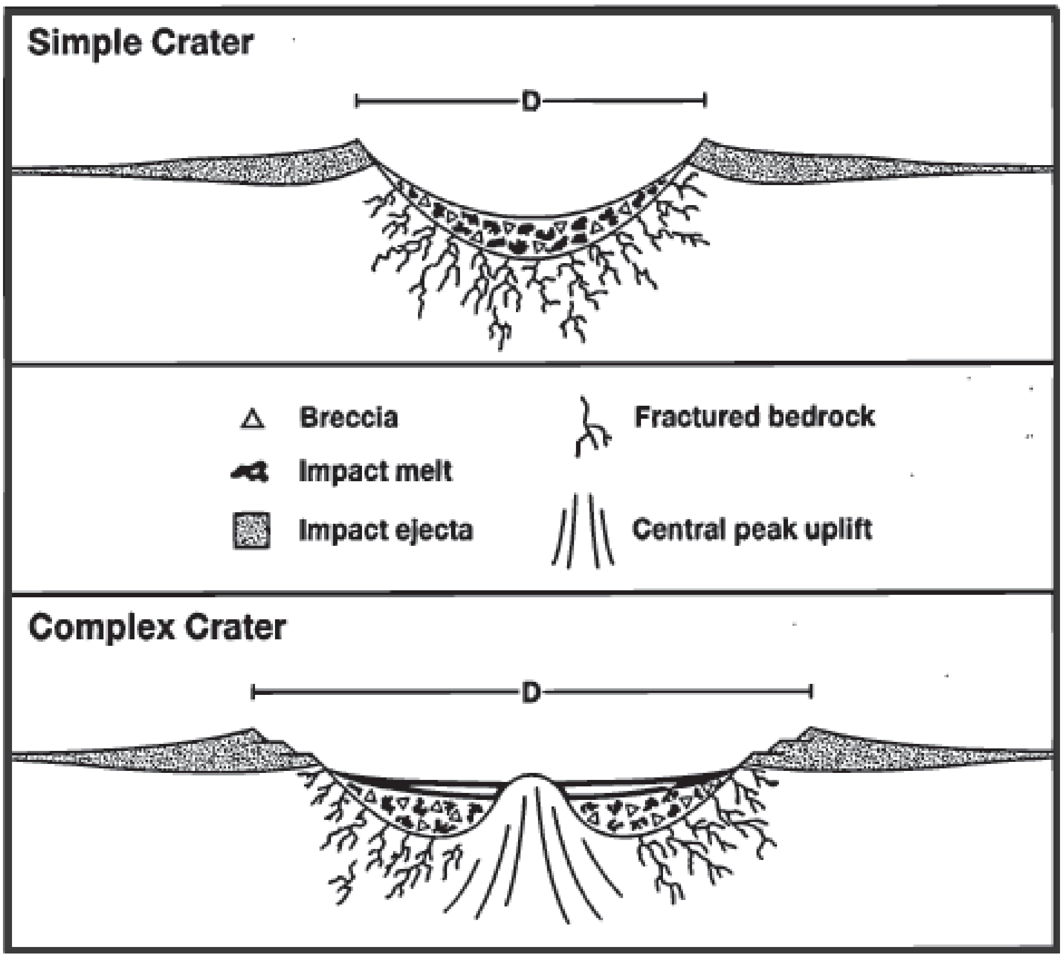
2. Craters: the rugged face of the planet

2. 1 Introduction

The projectile path of the asteroid within the gravitational field of the larger planet depends on (a) mass and (b) velocity. The path of the asteroid may slightly or entirely change from a parabolic manner to a closed orbit of elliptical nature. On the other hand, an asteroid passing by a larger planetary body does not have enough velocity, the centrifugal force is not enough to balance the gravitational force of attraction, resulting in the eventual collision of the body. These colliding bodies are called *meteorites*, and the structure that is made on the surface of the planetary body due to collision is called an *impact crater*.

The solid rock acts partially as a fluid under the intense force of impact of an object hitting at a velocity of thousand km. per second. The impact with the surface of a planet initiates an orderly sequence of events that eventually produces an impact crater and associated morpho-tectonic features.

Fresh impact craters can be grossly characterized as “circular rimmed depressions.” Although this description can be applied to all craters, independent of size, the detailed form of craters vary with size, substrate material, planet, and age. Craters have been observed over a range of sizes varying from 0.1 μm observed on lunar rocks brought back by the Apollo astronauts, to the more than 2000 km diameter as in Hellas Basin on Mars (Refer to **http://www.psi.edu/epo/explorecraters/hellastour.htm** for more details).



2. 2 Types of crater:

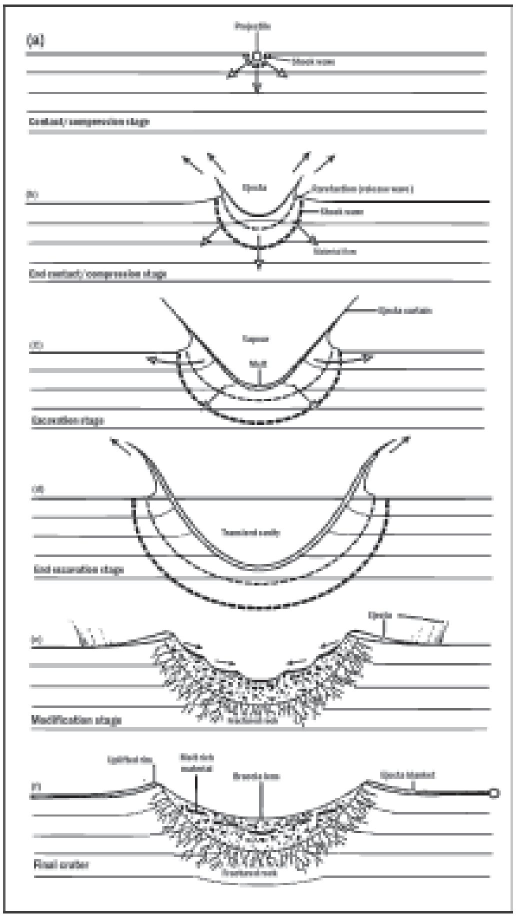
A common progression of morphologic features with increasing size has been used to establish a division of craters.

2.2.1 Simpe crater:

Simple crater are commonly less than 15 km (on Moon) and 3 - 6 km (on Earth) in diameter, their interiors are smoothly sloping with a parabolic profile (Fig 1a) and its rim-to-floor depth is about 1/5 of its rim-to-rim diameter. The rim is sharp crested and stands up about 4% of the crater diameter above the surrounding plain.

Outside the rim, a circular area with a radius thrice the crater radius is blanketed with a mixture of ejecta and debris scoured from the pre-existing surface. Fields of small secondary craters and bright rays of highly pulverized ejecta that extend many times the diameter of the crater away from the primary crater may surround simple craters.

The floor of simple crater is underlain by a lens of broken rocks called breccia. This breccia typically



includes representatives from all the formations intersected by the crater and may contain horizons of melted or highly shocked rock. The thickness of this breccia lens is typically 1/2 to 1/3 of the rim-to-floor depth.

2.2.2 Complex crater:

Complex craters are larger than 20 km (on Moon) and about 3 km (on Earth) in diameter. They have terraced walls, central peaks, and at larger sizes, sometimes flat interior floors or internal rings instead of central peaks (Fig 1b). These craters are believed to have formed by the collapse of an initially bowl-shaped “transient crater,” and because of this, these more complicated structures are known as “complex craters”. The most notable structural feature of complex craters is the uplift beneath their centers.The central peaks contain material that is pushed upward from the deepest levels excavated by the crater. As crater size increases, the central peaks characteristic of smaller complex craters give way to a ring of mountains. The ejecta blankets of complex craters are generally similar to those of simple craters, although radial troughs and ridges replace the “hummocky” texture characteristic of simple craters as size increases.

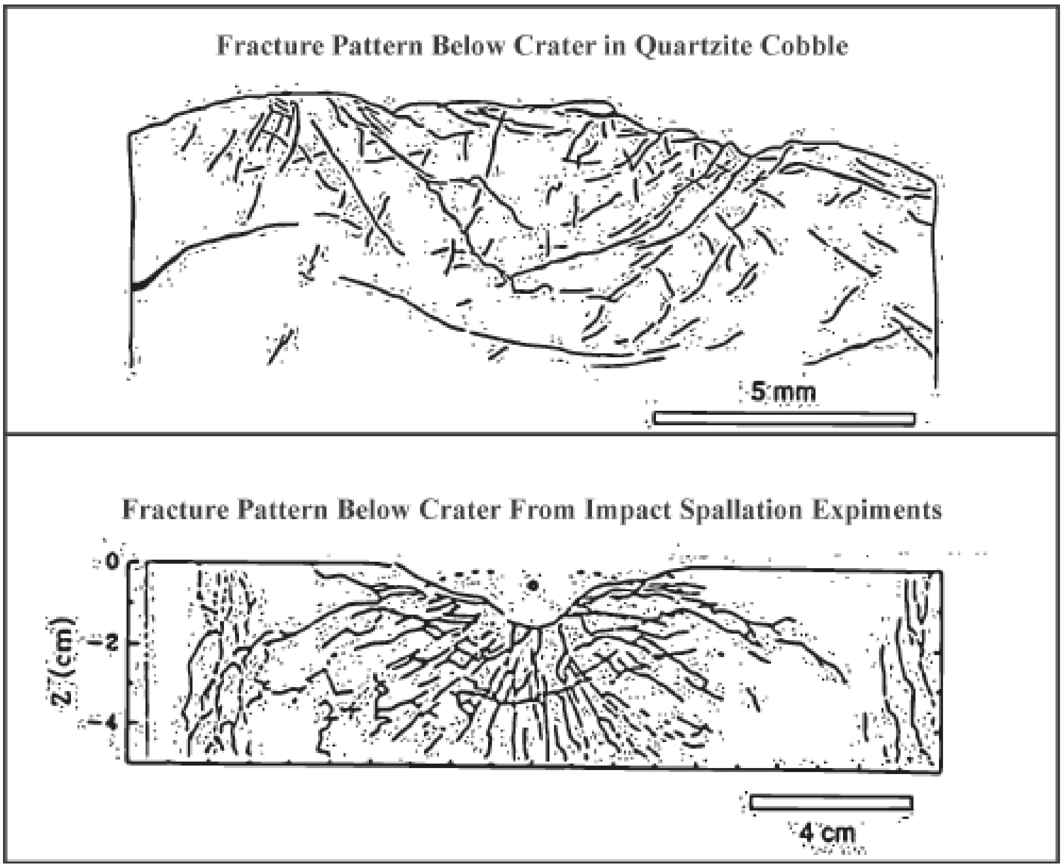
The floors of complex craters are covered by molten and highly shocked debris, and ocassionally melt pools are seen in depressions in the surrounding ejecta blanket. The surfaces of the terrace blocks tilt outward into the crater walls, and melt pools are also common in the depressions thus formed.

2.2.3 Multiring basin:

Multiring basins area the largest impact structures characterized by multiple concentric circular scarps. Multiring basins are common on the Moon, the most famous being the 930 km diameter Orientale basin., which has at least four nearly complete rings of inward-facing scarps. Most of them have recognizable ejecta blankets characterized by a radial ridge-and-trough pattern. Where the smallest has a diameter of 410 km.

3. Mechanics of impact Cratering:

The entire phenomenon of impact cratering is a continuum of several discrete processes / stages, each dominated by different physical



processes. It should not be forgotten that though discrete, the different stages actually grade into one another. These different stages can be divided into (a) **contact and compression** (b) **excavation**, and (c) **modification**. (Fig 2)

3.1 Contact and Compression:

3.1.1 Dynamics

In this stage, the projectile hits the target and transfers its energy and momentum to the receiver surface, generating strong shock waves as both objects are compressed. As the projectile plunges into the target, shock waves propagate both into the projectile, compressing and slowing it, and into the target, compressing and accelerating it radially outward.

The shock wave in the projectile eventually reaches its back (or top) surface, causing a release in pressure. The surface of the compressed projectile therefore expands upward and a wave of pressure relief propagates back downward toward the projectile–target interface. It is generally held that the contact and compression stage ends when this relief wave reaches the projectile–target interface. (Fig 3)

At this time the projectile has been compressed to high pressure and upon decompression it may be in the liquid or gaseous state due to internal heat generated during the irreversible compression process. The projectile generally carries off 50% or less of the total initial energy, and the balance of the energy is expended in opening the crater as well as heating the target.

3.1.2 Impact result

Contact and compression are accompanied by the formation of very high-velocity jets of shocked rockmass (Impact Rocks are described separately in section 3.2.2). These jets form where strongly compressed material is close to a free surface and the velocity depends on the angle between the converging surface of the projectile and target.

3.1.3. The impact clock

Contact and compression is the briefest of the three stages, lasting only a few times longer than the time required for the impacting object to traverse its own diameter. Contact and compression is the briefest of the three stages, lasting only a few times longer than the time required for the impacting object to traverse its own diameter.

3.2 Excavation:

3.2.1 Dynamics

The shock wave, created during the previous stage, expands and eventually weakens into an elastic wave. The crater itself is opened by the much slower "excavation flow".

The growing crater is at first hemispherical in shape (Simple crater). Initially its depth and diameter both increase simultaneously, but the diameter growth outlasts the depth excavation. The crater shape, thus, becomes a shallow bowl, finally attaining a diameter roughly three to four times its depth. At this stage, before collapse modifies it, the crater is known as a transient" crater. Even simple craters experience some collapse (which produces the breccia lens), so that the transient crater is always a brief intermediate stage in geological crater formation.

3.2.2. Crater rocks and material transfers

A high pressure is attained during the contact and compression stage and is uniformly distributed radially outwards from the point of impact over a volume roughly comparable to the initial dimension of the projectile. This region is called the isobaric core. The shock wave created during the impact, expands away from the impact site and the shock pressure decreases as the initial impact energy is spread out. The energy is also lost by heating the target. The shock wave, with a release wave immediately following, quickly attains the shape of a hemisphere expanding through the target rocks. The high shock pressures are confined to the surface of the hemisphere while the interior gets decompressed.

The velocity of shock waves vary from 6 and 10 km /s in most rocks, faster than sound. Rocks in the target are overrun by the shock waves, and then released to low pressures. This may yield to a change of mineralogy in the target rocks. A high pressure-low temperature impact metamorphism takes place. At the highest pressures the rocks may melt or even vaporize upon release. Lower pressures create a characteristic cone-in-cone fracture called shatter cones. They are readily recognized in the vicinity of impact structures and acts as an indicator of them. Many terrestrial impact structures were first recognized from the occurrences of shatter cones.

The weakening shock wave eventually degrades into elastic waves. These elastic waves are similar to the seismic waves produced by an earthquake. Seismic waves produced by a large impact may have significant effects on the target planet, creating jumbled terrains at the antipode of the impact site if they are focused by internal planetary structures, such as a low-velocity core.

Vaporized projectile and target, due to heating, may expand rapidly out of the crater, forming a vapour plum. If this is massive enough, it may blow aside any surrounding atmosphere and accelerate to high speed. In case of some large and fast projectiles, some of this vapour plume material may even reach escape velocity and leave the planet, incidentally also removing some of the planet's atmosphere.

The vapour plume may temporarily blow aside the atmosphere even in smaller impacts, opening the way for widespread ballistic dispersal of melt droplets called tektites above the atmosphere and perhaps permitting the formation of lunar-like ejection blankets even on planets with dense atmospheres. This kind of tektite horizon is seen in Earth at the K-T boundary rocks.

3.3 Modification:

3.3.1 Dynamics

Shortly after the excavation flow has opened the transient crater and the ejecta have been launched onto ballistic trajectories, a major change takes place in the motion of debris within and beneath the crater. Instead of flowing upward and away from the crater centre, the debris comes to a momentary halt, and then begins to move downward and back toward the centre from where it came. This collapse is generally attributed to gravity, although elastic rebound of the underlying, compressed rock layers may also play a role. The effects of collapse range from mere debris sliding and drainback in small craters to wholesale alteration of the form of larger craters in which the floors rise, central peaks appear, and the rims sink down into wide zones of stepped terraces. Great mountain rings or wide central pits may appear in still larger craters. The effects of collapse depend on the size of the crater.

The detailed mechanism of collapse is still not fully understood because straightforward use of standard rock mechanics models does not predict the type of collapse observed. The current best description of complex crater collapse utilizes a phenomenological strength model in which the material around the crater is approximated as a Bingham fluid, a material that responds elastically up to differential stresses of about 3 MPa, independent of overburden pressure, and then flows as a viscous fluid with viscosity of the order of 1 GPa-s at larger stresses.

The mechanics of the collapse that produces multiring basins is even less well understood. One idea that is currently gaining ground is that the ring scarps are normal faults that develop as the crust surrounding a large crater is pulled inward by the flow of underlying viscous mantle material toward the crater cavity.

3.3.2 Crater collapse

For transient craters smaller than about 15 km diameter on the Moon, or about 3 km on the Earth, modification entails only collapse of the relatively steep rim of the crater onto its floor. The resulting "simple crater" is a shallow bowl-shaped depression with a rim-to-rim diameter about five times its depth below the rim. Spectacular collapse is exhibited by complex craters. Wall slump, the uplifted floor, central peaks and the impact melt upon the floor testifies to the features within a collapsed crater

Occurrence: Impact craters are best preserved on the terrestrial planets like the Moon and the Mars which serve as a natural laboratory for their study. . Cratering is a natural phenomenon on their surfaces shaping their landforms. It is due to the lack of earth-like tectonic activity within these planets, even very old craters are preserved. On the other hand, crustal recycling due to tectonism has obliterated any old craters on the surface of the earth. Only craters that have formed in the Cainozoic are preserved. A few such examples are the crater of Arizona, Chixculub of Mexico and Ramgarh crater of India. Moreover the Earth's atmosphere burns off the smaller meteorites before reaching the earth's surface.

References: i. Stuart Ross Taylor and Scott m. McLennan, Planetary Crusts: Their Composition, Origin And Evolution, Cambridge University Press.

ii. H. Jay Melosh, Planetary Surface Processes, Cambridge University Press.

Acknowledgement: I am thankful to Almighty for giving me a chance to be a student of Department of geology, Presidency University. I am indebted to the Department for everything that I have.

India Joined With Asia 10 Million Years Later Than Previously Thought

Sourav Datta, *B.Sc 3rd Year*

The Himalayas we see today are just the modern remnants of massive tectonic forces that 'fused' India with Asia tens of millions of years ago.Previous estimates have suggested this collision occurred about 50 million years ago,as India moving northward at a rapid pace crushed up against Eurasia.Geologists have sought to characterize the rocks of the Himalayas in order to retrace one of theplanet's most dramatic tectonic collisions.

Recently researchers at MIT have found that the collisions between India and Asia occurred only 40 million years ago-10 millions later than previously thought.The scientists analyzed the composition of the rocks from two regions in the Himalayas and discovered evidence of two separate collisional events:As India crept steadily northward,it first collided with a string of islands 50 million years ago,beforeplowing into the Eursian continental plate 10 million years later.

How great was Greater India ?

Oliver Jagoutz (assistant professor of geology at MIT's Dept. Of Earth,Atmosphere and Planetary sciences,saysthe group's finding may change scientists' ideas about the size of India before it collided with Asia.At the time of collision,part of the ancient Indian plate-known as "Greater India"-slid underneath the Eurasian Plate.What we see of Indian's surface today is much smaller than it was 50 million years ago.It's not clear how much of India lies beneath Asia,but scientists believe the answer may come partly from knowing how fast the Indian plate migrates and exactly when the continent collided with Asia.

By dating the Indian-Eurasian collision to 10 million years later than previous estimates,Jagoutz and his colleagues conclude that Greater India must have been much smaller than scientists have thought-India moved more than 10 centimeters a year and 10 million years is 1000 kilometers less in convergence.

To pinpoint exactly when the Indian-Eurasian collision occurred,the team first looked to a similarbut more recent tectonic example.Over the last 2 million years,the Australian continental plate slowly collided with a string of islands known as the SundraArc.Geologists have studied the region as an example of an early stage continental collision.The researchers identified two main isotopic systems in the region's rocks-one in which the element lutetium decays to hafnium and another in which samarium decays to neodymium.From the analysis the researchers found that rocks high in neodymium and hafnium isotopes likely formed before Australia collided with the islands.Rocks low in neodymium and hafmium probably formed after the collision.

Once the team identified the isotopic signatures for collision,it looked for similar signatures in rocks gathered from the Himalayas.

Since 2000,Jagoutz has trekked to the northwest corners of the Himalayas,a region of Pakistan and India called the Kohistan-LadakhArc.This block of mountains is thought to have been a string of islands that was sandwiched between the two continents as they collided.Jagoutz traversed the mountainous terrain with pack mules and sledgehammers,carving out rock samples from the region's northern and southern borders.His team has brought back three tons of rocks,which he and his colleagues analyzed for signature isotopes!

The researchers split the rocks and separated out more than 3000 zircons -100 to 200 micron long crystals contining isotopic ratios.Jagoutz and his colleagues first determined the age of each zircon using another isotopic system,in which uranium turns slowly to lead with time.The team then measured the ratios of strontium to neodymium and lutetium to hafnium,to determine the presence of a ollision,keeping track of where each zircon was originally found(along the region's northern or southern block)

The team found a clear signature:Rocks older than 50 million years contained exactly the same ratio of isotopes in both the northern and southern samples.HoweverJagoutz found rocks younger than 50 million years,along the southern boundary of the Kohistan-Ladakh Arc suddenly exhibited a rage of isotopic ratios ,indicating as dramatic tectonic event.Along the arc's northern boundary,the same sudden change in isotopes occurs,but only in rocks younger than 40 million years.

Taken together,the evidence supports a new timeline of collisional events.Fifty million years ago,India collided with a string of islands,pushingtje island arc northward.Ten million years later,India collided with the Eurasian plate,sandwiching the string of islands,now known as the Kohistan-LadakhArc,between the massive continents.

Indian Tectonics and Earthquakes

Dipayan Banerjee, *B.Sc 3rd Year*

ABSTRACT:

The first ever Earthquake on Indian land recorded dates back to September, 1737, and since then, a large number of tremors have been recorded, be it mild or large. Since 1991, more than 35 mild to extreme earthquakes have been recorded in the Indian subcontinent. All these earthquake sequences were studied and used to understand the seismotectonics of the SCR events, collision zone and the subduction zone of the Indian subcontinent.

TECTONIC SETTING OF INDIA:

Peninsular India constitutes one of the most prominent and largest Precambrian shield areas of the world. It is exposed to the south of the Indo Gangetic Alluvial Plains (IGAP) which separates the Himalayas to the north and the peninsular India to the south. The major prominent rifts which separate the northern and southern blocks of the shield are the Narmada Son Lineament (NSL) and the Tapti Lineament (TL), together called the SONATA (Son-Narmada-Tapti Lineament) zone, which is about 1000 km long and 50 km wide in the central part of India. The other prominent rift is the Kutch rift at the NW margin of Indian shield.

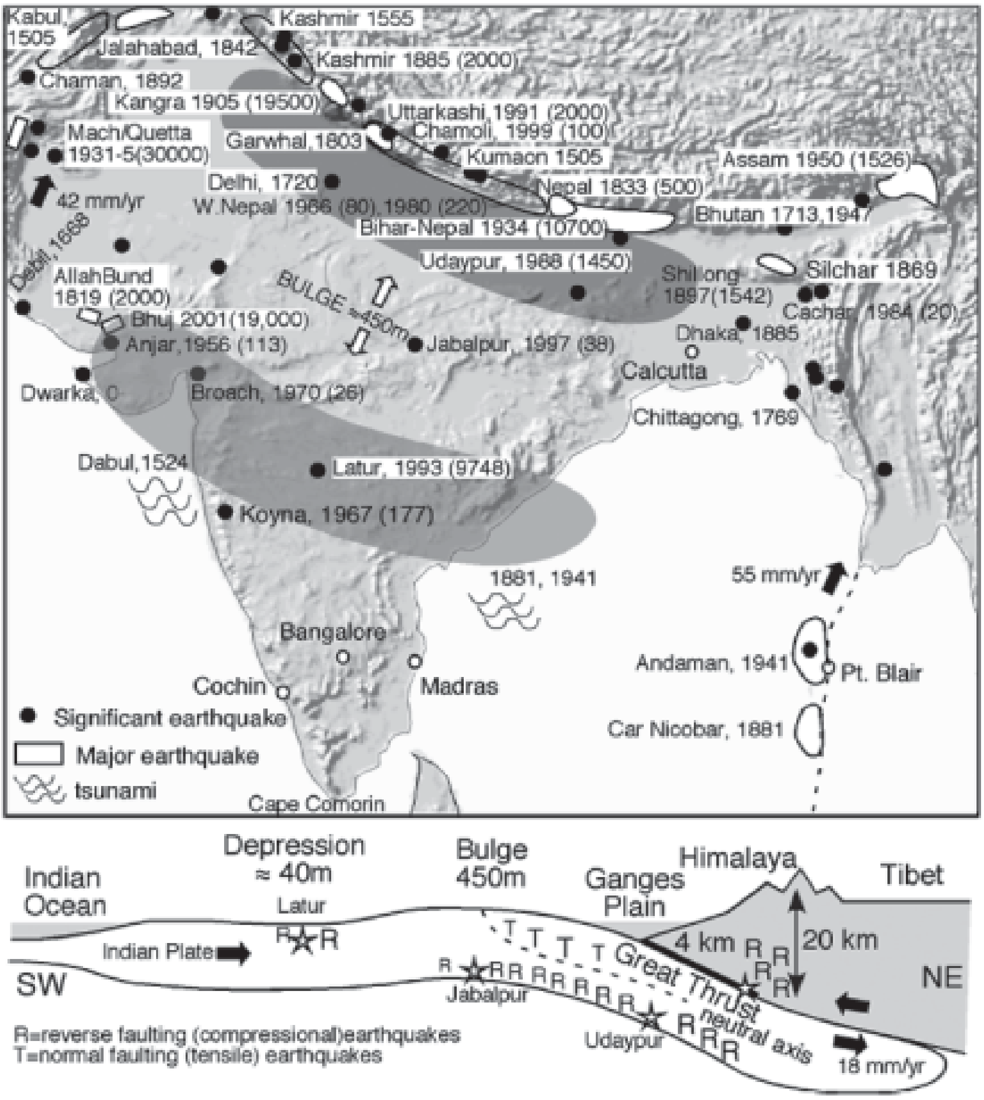
To the North, the Himalayas extending over 2500 km long evolved as a consequence of collision of the Indian and Asian continents some 50mya.The major thrust/fault systems present over the entire length of Himalayan Arc, from North To South are: the Indus Suture Thrust (IST), the Main Central Thrust (MCT), the Main Boundary Thrust (MBT) and the Himalayan Frontal Thrust (HFT). The seismicity between the MCT and MBT is known as the Main Himalayan Seismic Belt (MHSB).

The Himalayan Arc joins the Burma-Andaman-Sumatra-Sunda Arc to the SE that defines a ~5,500 km long boundary between the Indo-Australian and Eurasian plates from Myanmar to Sumatra and Java to Australia (Curray et al., 1970). Global reconstructions suggest that the Indian plate converges obliquely toward the Asian plate at a rate of 54mm/yr (DeMets et al.,1994).India is currently penetrating into Asia at a rate of approximately 45mm/yr and rotating slowly anticlockwise (Sella et al.,2002).This rotation and translation results in the left-lateral transform slip in Baluchistan at approximately 42mm/yr and right-lateral slip relative to Asia in the Indo-Burman ranges at 55mm/yr. Deformation within Asia reduces India's convergence with Tibet to approximately 18mm/yr (Wang et al.,2001) and because Tibet is extending east-west, convergence across the Himalaya is approximately normal to the arc. Arc-normal convergence across the Himalaya results in the development of potential slip available to drive large thrust earthquakes beneath the Himalaya at roughly 1.8m/cy (Bilham et al., 1997).

The earthquakes occurred in three tectonic zones of the Indian subcontinent- Stable Continental (SCR) Zone, Himalayan Collision Zone and the Andaman- Sumatra Subduction Zone.

SCR Earthquakes in Peninsular India
The 2001 Bhuj Earthquake (M=7.7):

The most recent devastating Bhuj Earthquake of January 26, 2001 is one of the largest events occurred in the Stable Continental Zone. It is another example of a deeper paleo-rift basin earthquake within the SCR of Peninsular



India which occurred at a depth of 25km in the Kutch Rift Basin. The seismic sections and the fault plane solutions illustrates that the main shock originated at the base of the paleo-rift basin by reverse faulting on a deep seated south dipping hidden fault; the rupture propagated along NE as well as NW. Also the Kutch Mainland Fault which runs E-W in the central part of the basin is not the causative fault for the Bhuj Earthquake sequence; a steeply South dipping hidden fault which did not rupture to the surface generated the main shock at deeper depth and the rupture propagated to the NE and NW at depth to generate the aftershocks.

HIMALAYAN COLLISION ZONE EARTHQUAKES

The 1991 Uttarkashi Earthquake (M=6.6):

The Uttarkashi Earthquake of October 20, 1991 occurred in a complicated Tectonic setting in the Western Himalayan Collision Zone. The main shock occurred at a depth of 15km and the aftershocks occurred at 0-15km depth. The fault plane solution of the main shock shows a low angle thrust faulting and the aftershocks show a reverse faulting. The main shock and all of the aftershocks occurred on and above the Plane of Detachment. The North-dipping nodal plane of the fault plane solution of the main shock confirms well with the low angle north dipping basement thrust or Plane of Detachment and the steeply north dipping nodal plane of the composite fault plane solution of the aftershocks confirms well with the dip of the Uttarkashi fault that merges on the Plane of Detachment.

ANDAMAN-SUMATRA SUBDUCTION ZONE EARTHQUAKES

The 2004 Sumatra-Andaman Tsunami Earthquake (M=9.3):

The December 26,2004 Sumatra-Andaman Earthquake occurred by Thrust faulting on the Interplate Thrust Zone of the subducting Indian plate and overriding Burma plate. The main shock rupture,~1300 km long, generated the Tsunami in the Bay of Bengal and the Indian Ocean. There is a predominant Thrust faulting in the fore-arc region along the West Andaman Fault and the normal/strike slip in the back-arc region along the Andaman Sea Ridge consistent with the regional tectonics.

CONCLUSION:

Since 1990, as many as 11 strong to mega earthquakes (M= 6.0-9.3) severely rocked the Indian subcontinent causing huge loss of human lives and properties.

The 2001 Bhuj Earthquake neither produced surface rupture nor occurred on a known surface fault; it was caused by a deep seated hidden fault. Deeper source of the Earthquake at a depth of 35km at the 'fault end' of the paleo-rift basin, the Narmada South fault at the basin margin reactivated to generate the Earthquake at the crust-mantle boundary.

The 1991 Uttarkashi Earthquake supports the steady state tectonic model of the Himalaya that suggests that the strong/large earthquakes occur on the Detachment Plane or Basement Thrust at the 'fault ends'. The investigations further revealed that the MCT is dormant;

the active segments of the faults to the south of MCT are the causative faults for the Himalayan seismicity.

The 2004 Andaman-Sumatra Subduction Zone Earthquake is one of the largest subduction zone events in the world. The fault plane solutions of the main shock and aftershocks revealed the complex tectonics of the region.

Annals of Geophysics, Vol. 47,N.2/3,April/June 2004, Earthquakes in India and the Himalaya: tectonics, geodesy and history, Roger Bilham.

Recent Large Earthquakes in India: Seismotectonic perspective, J.R. Kayal.

IPDS – Listening To The Voice of Oil

Dyuti Prakash Sarkar *M.Sc. 1st Year*

Infrasonic Passive Differential Spectroscopy (IPDS) is technology that was developed in 1995 for direct detection and monitoring of hydrocarbon deposits for the first time in the history of petroleum industry. This technology is based on the principles of nonlinear behavior of fluid systems in porous media. Low frequency Acoustic Spectroscopy was previously used in different research fields, especially in different military, medical and seismological applications. This science is also the most popular method and frequently used for recording natural events in earth hazard prediction and Vulcanlogy. However in 1995, a small group of scientists, converted the experiences from military applications to oil industry, applying low frequency acoustic spectroscopy for direct detection of hydrocarbons in the subsurface reservoirs. During the initial experiment in 1997, for the first time in the history of oil industry, it wasdiscovered that, on top of an oil reservoir, the natural earth noise spectra show an increase of magnitude in the frequency range between 0 and 6 Hz. The identification of this phenomenon was subsequently, developed as Infrasonic Passive Differential Spectroscopy. Since then it has been applied in many surveys giving a positive confirmation in more than 80% of the cases, which is quite a relevant rate of success compared to other indirect investigations adopted in oil and gas exploration.

IPDS is geophysical technique of HC exploration categorized under Passive seismic. Generally there are three categories of passive seismic. These are passive acoustic spectroscopy, passive reflection seismic, and passive micro-event monitoring. Passive low-frequency seismic for exploration received new and high attention when Dangel et.al. in 2003 reported amplitude peaks clustered around 3Hz in seismicdata measured above hydrocarbon-bearing reservoirs in the Middle East. The key observation was that seismic background noise seemed to be modified in the low frequency range above hydrocarbon filled structures relative to the background noise measured above water filled structures.

Seismic *background noise:*

The earth's surface is always in motion at seismic frequencies. These vibrations of the surface are called microseisms, micro tremors, or simple seismic background noise. Although the vibrations are very small in amplitude, and far below human sensing, they may represent a useful source of signal that can be used to analyze the response of *the ground to earthquake movement. Micro tremor surveying basically is a passive seismic method that is relevant for engineering geophysics in densely populated areas where there is a difficulty in using conventional seismic techniques. The nature of micro-tremors has been vigorously debated. Recent literature debated whether micro-tremors are dominated by S-wave resonances or by Rayleigh wave propagation. However, it is accepted that micro-tremors are caused by both daily human activities as well as natural phenomena. Examples of human activities are motor cars and movement of machinery in factories, which typically produce micro-tremors with signal components higher than 1 Hz in frequency. Natural phenomena are ocean waves, variations in atmospheric pressure, and wind. The corresponding micro-tremors are dominated by signal frequency components lower that 1 Hz. The most energetic part of this background noise is frequencies around 0.2 Hz, and is most likely related to seismic surface waves generated by ocean waves.*

Reference: Okada H 2003: The microtremorsurvey method: Society of Exploration Geophysicists

IPDS deals with passive acoustic spectroscopy and it detects the presence or absence of a petroleum containing reservoir. The frequency of the recorded wave is infra or less than normal sound waves. In this method no artificial sound, e.g., explosives or vibrations, is used; the record of the passive sound of earth only

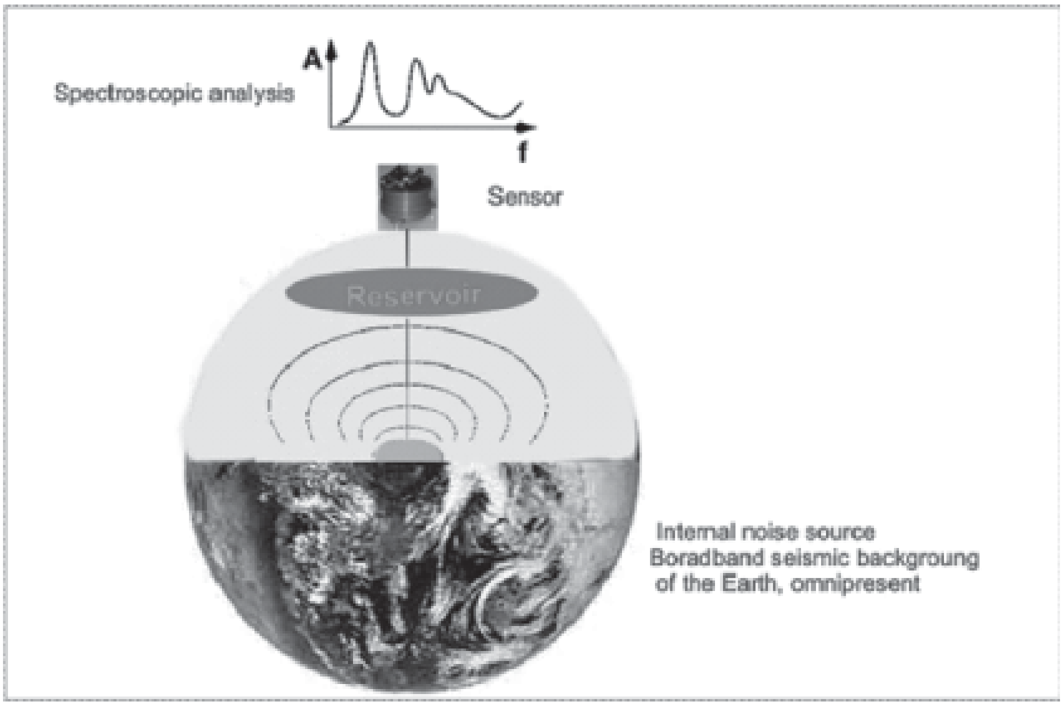


Fig. 1: Schematic acoustic spectroscopic signature of a subsurface hydrocarbon reservoir.

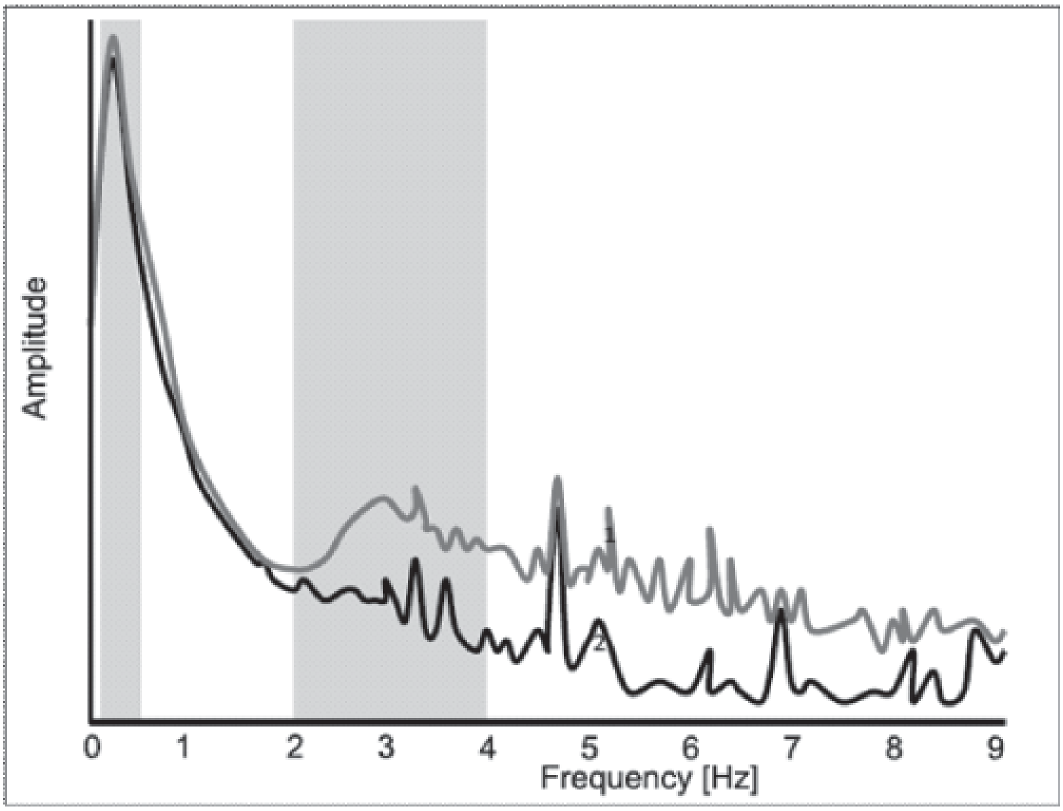


Fig.2 : Amplitude spectra characteristic of measurements of seismic background noise within (curve 1) and outside (curve 2) the boundaries of a known oil reservoir in the Potiguar Basin, Brazil. The curves are hand-drawn after Graf et al (2007). The right bar highlights the frequency band where hydrocarbon anomalies are usually found. The left grey bar highlights were the noise from ocean waves is found.

is utilized. This technology works only when differential media is present in the reservoir i.e. oil and water or oil/gas and water. Spectroscopy is the processing technique of those signals, interpreting anomalies representing the presence or absence of hydrocarbons. The principle of this method is that a hydrocarbon reservoir is a frequency converter. It deforms the frequencies of the ubiquitous earth noise.

What causes the spectral anomalies?

The precise physical mechanisms causing the spectral anomalies are still the subject of active research. However, two potential causes has been proposed. The first is the resonant amplification occurring at the pore scale within the reservoir, whereby seismic energy is trapped in a multiphase fluid system and then emitted with detectable energy levels. Secondly, at the macro scale, resonant scattering due to complex impedance contrasts between the hydrocarbon bearing rock and the surrounding media alter the ambient seismic wave-field to become detectable at low frequency. Interestingly, there are some ideas suggesting that this signal can be enhanced by natural phenomenon such as earthquakes or using active sources, such as vibroseis.

Instruments, data acquisition and processing:

Patented sensors measure the sound waves. These sensors are seismometers with the sensitivity of 30,000 – 120,000 V Sec/m (a normal I/O geophone shows in this frequency range a sensitivity of 28 V Sec/m). The instrument is an electrodynamic, inverse loop magnetic system which is self-calibrating and can record frequency between 0.1 – 40 Hz.

IPDS data acquisition is done by placing the sensors as planned in the measurement set-up. Normally measurements are taken at 4-6 recording points (data points) at the same time, using one or two six channel recorders. The recording time is not less than 40 minutes (standard). For initial exploration of hydrocarbons the spacing maybe some kilometers. Once the target has been identified, the spacing maybe 150m or less.

The recorded signals are transformed from the time domain to the frequency domain where their spectral signatures are analyzed. The raw signal recorded is strongly dependent on environment noise and on stochastic variation of the white earth noise spectra. For this reason, the raw signals are filtered before and after transformation in the frequency domain.

Applications and Objectives:

The technology has been widely used in over 100 field application, e.g. the Qushwahira, Bu Hasa, Marghan and Shag oil and gas fields of ADCO, UAE; the East Moldavek and Nurznanov fields of Kajumunayagaz, Kazaksthan; the Tanehill prospect, Young County, Texas and other fields in USA; OML-277, Nigeria; Bantumilli, K-G Basin and Sanganpur, Cambay Basin, India.

The main objective of the Passive Seismic survey campaigns was to run such surveys as exploration, delineation, reservoir monitoring and time laps monitoring tool under any kind of geographic conditions or with any type of geological system, structure, stratigraphic and lithology (sandstone, limestone, igneous, salt, anhydrite, etc.) it will have no effects on low frequency anomalies. However, the main effect is to determine whether hydrocarbons exist or not in a porous media. The secondary objective was to provide information concerning detailed lateral and vertical hydrocarbon distributions away from oil control points (quantity and quality), and more recent studies are being conducted to develop the technology for addressing the detection of hydrocarbon depth and possibly the staking pattern of the reservoirs.

In oil field monitoring, IPDS screens the oil/gas producing areas, determines the location of infill wells, identifies the bypass or attic oil, uneven flood fronts, and ineffective draining. In abandoned and depleted fields, this technology has been used to ascertain the presence of leftover oil in the field. It is a giant cost saver in exploration, field development, field monitoring, and in depleted-abandoned fields.

Conclusion:

IPDS is an illustrative tool with high value of information content because it directly indicates the presence of hydrocarbon. It identifies the locations for wild cat wells, delineation wells with greatest chance of success and drastically reduces the risk of drilling dry wells. Hence, it is a quite promising technology for petroleum industry. However, technology is analogous to language, and like all languages, it is always mutable and improving but never reaching absolute precision, rather each time taking an infinitesimal step towards perfection.

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Formation of Mineral Deposits of Igneous Origin

Srinjoy Sarkar, *B.Sc. 3rd Year*

Mineral Deposits form because some medium serves as a concentrating and transporting agent for the ore minerals, and some process subsequently causes the transporting agent to precipitate, or deposit, the minerals. Examples of concentrating and transporting agents are groundwater, seawater and magma. In this article we would discuss about the influence of magmatic activities on the formation of mineral deposits.

Magma is molten rock, together with any suspended mineral grains and dissolved gases that forms when temperatures rise and melting occurs in the mantle or crust. When magma rises to the Earth's surface through fissures and volcanic vents, it is called lava. Lava cools and crystallizes quickly, so that igneous rocks formed from lava tend to consist of tiny mineral grains (sometimes cooling can be so rapid that mineral grains cannot form and a glass results). Underground magma, on the other hand, cools and crystallizes slowly, and the resulting igneous rocks tend to contain mineral grains at least one-half centimetre (about one quarter inch) in diameter.

Pegmatite deposits: The crystallization of magma is a complex process because magma is a complex substance. Certain magmas, such as those which form granites, contain several percent water dissolved in them. When a granitic magma cools, the first minerals to crystallize tend to be anhydrous (e.g. Feldspar), so an increasingly water-rich residue remains. Certain rare chemical elements, such as lithium, beryllium, and niobium, which do not readily enter into atomic substitution in the main granite minerals (feldspar, quartz, and mica) become concentrated in the water-rich residual magma. If the crystallization process occurs at a depth of about five kilometres or greater, the water-rich residual magma may migrate and form small bodies of igneous rock, satellitic to the main granitic mass, that are enriched in rare elements. Such small igneous bodies, called rare-metal pegmatite, are sometimes exceedingly coarse grained, with individual grains of mica, feldspar, and beryl up to one meter across. Pegmatites provide an important fraction of the world's lithium, beryllium, cesium, niobium, and tantalum.

Carbonatite deposits: Carbonatites are igneous rocks that consist largely of the carbonate minerals calcite and dolomite, they sometimes also contain the rare-earth ore minerals bastnaesite, parasite, and monazite, the niobium ore mineral pyrochlore, and (in the case of the carbonatite deposit at Palabora in South Africa) copper sulphide ore minerals. The origin of carbonatite magma is obscure. Most carbonatites occur close to intrusions of alkaline igneous rocks (those rich in potassium or sodium relative to their silica contents) or to the ultramafic igneous rocks (rocks with silica contents below approximately 50% by weight) known as kimberlites and lamproites. These associations suggest a common derivation, but details of the way that carbonatite magmas might concentrate geochemically scarce metals remain conjectural.

Magmatic Cumulates: Magmatic segregation is a general term referring to any process by which one or more minerals become locally concentrated (segregated) during the cooling and crystallization of a magma. Rocks formed as a result of magmatic segregation are called magmatic cumulates. While a magma may start as a homogenous liquid, magmatic segregation during crystallization can produce an assemblage of cumulates with widely differing compositions. Extreme segregation can sometimes produce monmineralic cumulates; a dramatic examples occurs in Bushveld Igneous Complex of South Africa, where cumulus layers of chromite (iron-magnesium-chromium oxide, the only chromium ore mineral) are encased in cumulus layers of anorthite.

Mineral deposits that are magmatic cumulates are only found in mafic and utramafic igneous rocks. This is due to control exerted by silica on the viscosity of a magma, the higher the silica content, the more viscous a magma and the more slowly segregation can proceed. Highly viscous magmas, such as those of granitic composition, tend to cool and crystallize faster than segregation can proceed. In low-silica (and, hence, low-viscosity) magmas such as gabbro, basalt, and komatiite, mineral grains can float, sink, or be moved so rapidly by flowing magma that segregation can occur before crystalliation is complete.

Three ore minerals form magmatic

Fig: Cumulus Layers of the chromium ore mineral chromite(dark) alternating with layers of anorthite(white).

cumulates: chromite, magnetite, and ilmenite. The world's largest chromite deposits are all magmatic cumulates; the largest and richest of these is in the Bushveld Complex of South Africa. Cumulus deposits of magnetite make poor iron ores, because cumulus magnetites invariably contain elements such as titanium, manganese, and vanadium by atomic substitution- although vanadiferousmagnetites are important as source of vanadium. In fact, much of the world's production of this metal comes from cumulus magnetites in the Bushveld Complex.

Immiscible Melts: A different kind of magmatic segregation involves liquid immiscibility. A cooling magma will sometimes precipitate droplets of a second magma that has an entirely different composition. Like oil and water, the two magmas will not mix (i.e. they are immiscible). The chemical principle governing precipitation of an immiscible liquid is the same as that governing crystallization of a mineral from a magma; when the concentration of a particular mineral within a parent magma reaches saturation, precipitation occurs. If saturation is reached at a temperature above the melting point of the mineral, a drop of liquid precipitates instead of a mineral grain. The composition of this immiscible drop is not exactly that of the pure mineral, because the liquid tends to scavenge and concentrate many elements from the parent magma, and this process can lead to rich ore deposits.

Iron Sulfide is the principal constituent of most immiscible magmas, and the metals scavenged by iron sulphide liquid are copper, nickel, and the platinum group. Immiscible sulfide drops can become segregated and form immiscible magma layers in a magma chamber in the same way that cumulus layers form; then, when layers of sulfide magma cool and crystallize, the result is a depositof ore minerals of copper, nickel, and platinum group metals in a gangue of an iron sulfide mineral. Among the ore deposits of the world formed in this way are the Merensky Reef of the Bushveld Complex, producer of a major fraction of the world's platinum-group metals; the Stillwater Complex, Montana, host to platinum-group deposits similar to the Merensky Reef; and the Norilsk Deposits of Russia, containing large reserves of platinum-group metals.

Under suitable conditions, immiscible sulfide liquids can also become segregated from flowing lavas. An example is offered by the Kambalda nickel deposit in the Western Australia. At Kambalda a nickel ore mineral, pentlandite, together with valuable by-product minerals of copper and platinum-group metals, crystallized in an iron-sulfide-rich gangue from a sulfide liquid that had become segregated from a magnesium rich lava called a komatiite (named for the Komati river in South Africa).

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Moon's Dancing Tide

Ramit Mitra, *B.Sc 3rd year*

Introduction

NASA missions in orbit have for the first time allowed scientists to observe the Moon's "dancing tide" swaying with Earth's gravitational pull.Scientists combined observations from two NASA missions to check out the moon's lopsided shape and how it changes under Earth's sway — a response not seen from orbit before.

Studies have been made by NASA's Lunar Reconnaissance Orbiter, which has been investigating the moon since 2009, and by NASA's Gravity Recovery and Interior Laboratory, or GRAIL, mission. Because orbiting spacecraft gathered the data, the scientists were able to take the entire moon into account, not just the side that can be observed from Earth.The deformation of the moon due to Earth's pull is very challenging to measure, but learning more about it gives clues about the interior of the moon.

Some information about lunar reconnaissance orbiter :

The **Lunar Reconnaissance Orbiter** (**LRO**) is a NASA robotic spacecraft currently orbiting the Moon in a low 50 km (31 mi) polar mapping orbit.The LRO mission is a precursor to future manned missions to the Moon by NASA. To this end a detailed mapping program will identify safe landing sites, locate potential resources on the Moon, characterize the radiation environment, and demonstrate new technology.

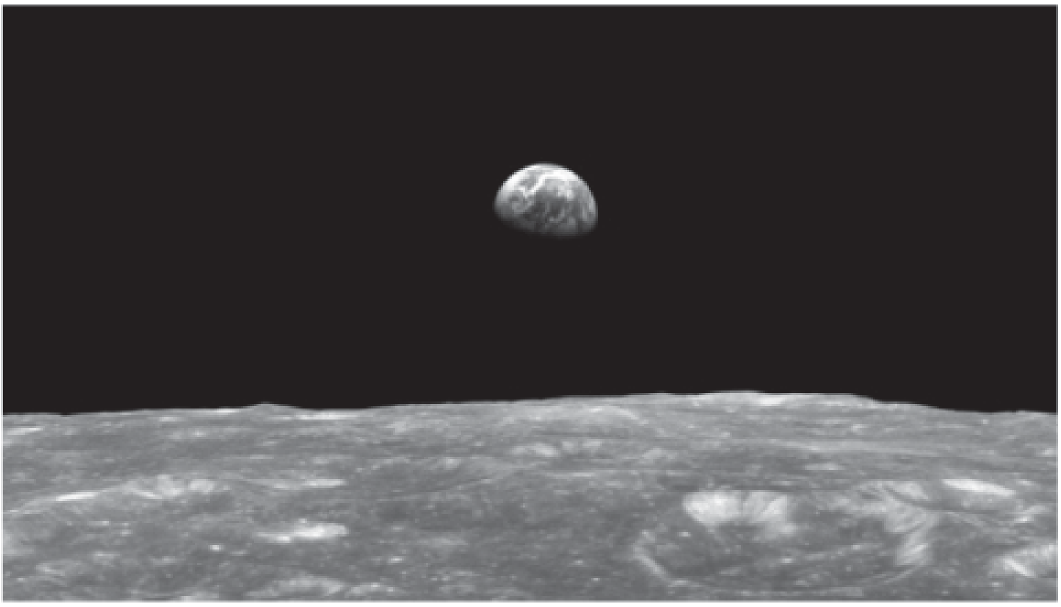
The probe will make a 3-D map of the Moon's surface and has provided some of the first images of Apollo equipment left on the Moon.

Some information about gravity recovery and interior laboratory :

The **Gravity Recovery and Interior Laboratory** (**GRAIL**) was an American lunar science mission in NASA's Discovery Program which used high-quality gravitational field mapping of the Moon to determine its interior structure. The two small spacecraft **GRAIL A** (**Ebb**) and **GRAIL B** (**Flow**) were launched on 10 September 2011 aboard a single launch vehicle: the most-powerful configuration of a Delta II, the 7920H-10. GRAIL A separated from the rocket about nine minutes after launch, GRAIL B followed about eight minutes later. They arrived at their orbits around the Moon 25 hours apart. The first probe entered orbit on 31 December 2011 and the second followed on 1 January 2012. The two spacecraft impacted the Lunar surface on December 17, 2012.

Objectives of GRAIL:

- Map the structure of the lunar crust



and lithosphere

- Understand the asymmetric thermal evolution of the Moon
- Determine the subsurface structure of impact basins and the origin of lunar mascons
- Ascertain the temporal evolution of crustal brecciation and magmatism
- Constrain the deep interior structure of the Moon
- Place limits on the size of the Moon's inner core

The data collection phase of the mission lasted from 7 Mar 2012 to 29 May 2012, for a total of 88 days. A second phase, at a lower altitude, of data collection began 31 Aug 2012, and will be followed by 12 months of data analysis. On 5 Dec 2012 NASA released a gravity map of the Moon made from GRAIL data. The knowledge acquired will aid understanding of the evolutionary history of the terrestrial planets and computations of lunar orbits.

Outcome of the mission :

The lopsided shape of the moon is one result of its gravitational tug-of-war with Earth. The mutual pulling of the two bodies is powerful enough to stretch them both, so they wind up shaped a little like two eggs with their ends pointing toward one another. On Earth, the tension has an especially strong effect on the oceans, because water moves so freely, and is the driving force behind tides.

Earth's distorting effect on the moon, called the lunar body tide, is more difficult to detect, because the moon is solid except for its small core. Even so, there is enough force to raise a bulge about 20 inches (51 centimeters) high on the near side of the moon and similar one on the far side.

NASA missions in orbit have allowed scientists to observe the Moon's "dancing tide" swaying with Earth's gravitational pull.

The position of the bulge actually

shifts a few inches over time. Although the same side of the moon constantly faces Earth, because of the tilt and shape of the moon's orbit, the side facing Earth appears to wobble. From the moon's viewpoint, Earth doesn't sit motionless but moves around within a small patch of sky. The bulge responds to Earth's movements like a dance partner, following wherever the lead goes.

"If nothing changed on the moon — if there were no lunar body tide or if its tide were completely static — then every time scientists measured the surface height at a particular location, they would get the same value," said Mike Barker, a Sigma Space Corporation scientist .

A few studies of these subtle changes were conducted previously from Earth. But not until LRO and GRAIL did satellites provide enough resolution to see the lunar tide from orbit.

To search for the tide's signature, the scientists turned to data taken by LRO's Lunar Orbiter Laser Altimeter, or LOLA, which is mapping the height of features on the moon's surface. The team chose spots that the spacecraft has passed over more than once, each time approaching along a different flight path. More than 350,000 locations were selected, covering areas on the near and far sides of the moon.

The measurements taken at the same spot and calculated whether the height had risen or fallen from one satellite pass to the next; a change indicated a shift in the location of the bulge.

A crucial step in the process was to pinpoint exactly how far above the surface LRO was located for each measurement. To reconstruct the spacecraft's orbit with sufficient accuracy, we need the detailed map of the moon's gravity field provided by the GRAIL mission.

This study provides a more direct measurement of the lunar body tide and much more comprehensive coverage than has been achieved before.

The good news for everyone is that the new results are consistent with earlier findings. The estimated size of the tide confirmed the previous measurement of the bulge. The other value of great interest to researchers is the overall stiffness of the moon,and this was also similar to prior results.

Having confirmation of the previous values — with significantly smaller errors than before — will make the lunar body tide a more useful piece of information for scientists.

This research shows the power of bringing together the capabilities of two missions. The extraction of the tide from the LOLA data would have been impossible without the gravity model of the moon provided by the GRAIL mission.

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The above article is based on materialsprovided by **NASA/ Goddard Space Flight Center**.

MYSTERY OF LOWER MANTLE

Ramit Mitra, *B.Sc 3rd year*

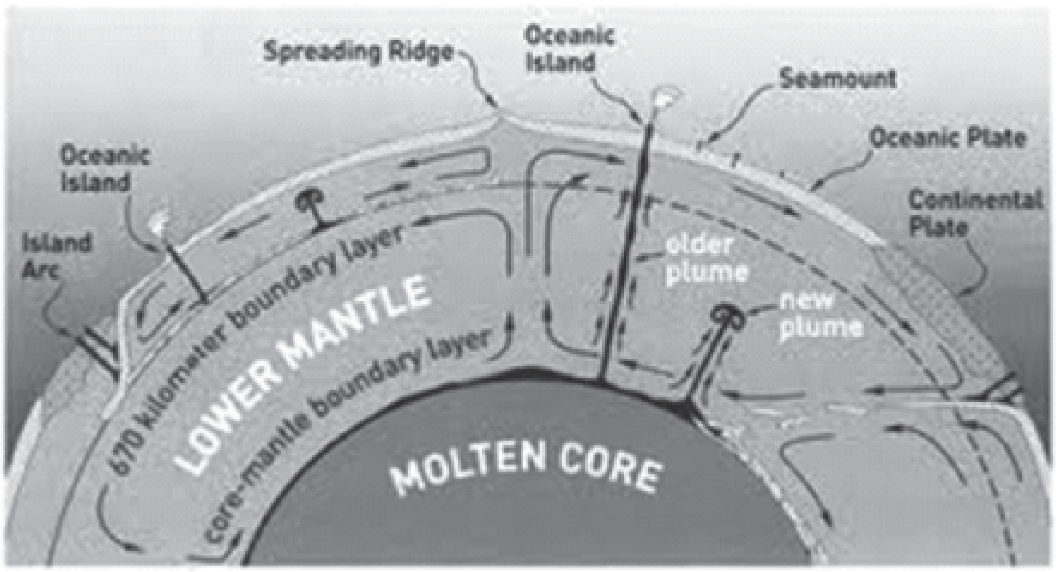
Information about lower mantle:

The lower mantle comprises 55 percent of the planet by volume and extends from 670 and 2900 kilometers in depth, as defined by the so-called transition zone (top) and the core-mantle boundary (below). Pressures in the lower mantle start at 237,000 times atmospheric pressure (24 gigapascals) and reach 1.3 million times atmospheric pressure (136 gigapascals) at the core-mantle boundary. Any living person would instantly be crushed under such pressure.It composes of chiefly magnesium- and iron-bearing silicates, including the high-pressure equivalents of olivine and pyroxene.

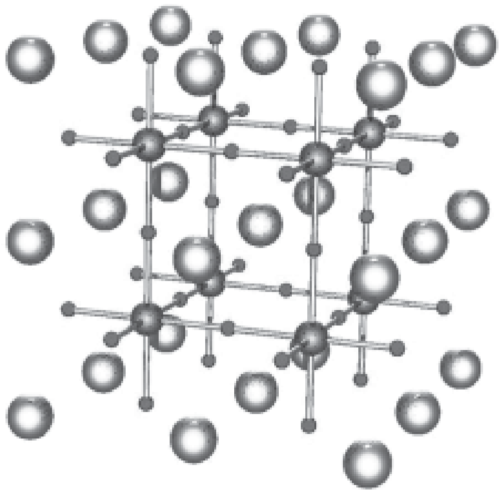
Mystery of lower mantle:

The prevailing theory has been that the majority of the lower mantle is made up of a single ferromagnesian silicate mineral, commonly called perovskite (Mg,Fe)SiO_3 defined through its chemistry and structure. It was thought that perovskite didn't change structure over the enormous range of pressures and temperatures spanning the lower mantle.

Recent experiments that simulate the conditions of the lower mantle using laser-heated diamond anvil cells, at pressures between 938,000 and



A view of interior earth.



997,000 times atmospheric pressure (95 and 101 gigapascals) and temperatures between 3,500 and 3,860 degrees Fahrenheit (2,200 and 2,400 Kelvin), now reveal that iron bearing perovskite is, in fact, unstable in the lower mantle.

Researches have found that the mineral disassociates into two phases one a magnesium silicate perovskite missing iron, which is represented by the Fe portion of the chemical formula, and a new mineral, that is iron-rich and hexagonal in structure, called the H-phase. Experiments confirm that this iron-rich H-phase is more stable than iron bearing perovskite, much to everyone's surprise. This means it is likely a prevalent and previously unknown species in the lower mantle. This may change our understanding of the deep Earth.

Some information about structure of perovskite :

The perovskite structure is adopted by many oxides that have the chemical formula ABO_3.

In the idealized cubic unit cell of such a compound, type 'A' atom sits at cube corner positions (0, 0, 0), type 'B' atom sits at body centre position (1/2, 1/2, 1/2) and oxygen atoms sit at face centred positions (1/2, 1/2, 0).

The relative ion size requirements for stability of the cubic structure are quite stringent, so slight buckling and distortion can produce several lower-symmetry distorted versions, in which the coordination numbers of A cations, B cations or both are reduced. Tilting of the BO_6 octahedra reduces the coordination of an undersized A cation from 12 to as low as 8. Conversely, off-centering of an undersized B cation within its octahedron allows it to attain a stable bonding pattern.

Conclusion :

The chemistry of the H-phase, is still a bit confusing and researches are going on till date. But this finding indicates that all geodynamic models need to be reconsidered to take the H-phase into account. And there could be even more unidentified phases down there in the lower mantle as well, waiting to be identified.

The Permo-Triassic Mass Extinction: An Enigma in Earth Science

Suranjan Ghosh, *M.Sc. 1st Year*

Introduction:

Several major biological crises technically called mass extinctions have hit the earth from time to time throughout its long history spanning the whole of Phanerozoic, for example Permian-Triassic Boundary, Cretaceous-Tertiary Boundary and. But among all of them, one mass extinction truly dwarfs all the others. Whereas earlier and later events each seem to have extinguished about 50% of species, the end-Permian Extinction was associated with a loss of 80-90% of species in the sea and in land. Several major groups just disappeared, including the trilobites and giant sea scorpions called eurypterids.

The vast scale of the extinction is shown by the fact that two major structural ecosystems disappeared- the Reefs and the Forests. Nothing like that has happened in any of the other mass extinctions.

Reefs first appeared in the Cambrian, and by the end-Permian had become a major ecosystem hosting substantial biodiversity, as they do today. With the loss of the dominant reef builders, the rugose and tabulate corals, the earth was cleared entirely of reefs. It took another 15 million years for new group of corals to evolve and build reefs once more.

Forests likewise virtually disappeared. There is a famous “coal gap” in the early and middle Triassic when no forests anywhere became sufficiently established to produce coal deposits. Key groups of forest insects, soil churners and vertebrates disappeared too. Searching for the cause or causes of this dramatic extinction has become an exciting task for Geoscientists. Can this extinction be linked with some of the catastrophic extra- terrestrial phenomenon or is it a gradual process as the traditional paleontologists have claimed so long?

Such a huge devastation of life might seem to imply a colossal impact. Evidence for this, however is weak to non-existent. The most favoured explanation is volcanic eruptions: 252 million years ago, when massive volcanoes erupted in Siberia and they continued to belch forth viscous basalt lava and massive clouds of gases for over 500,000 years. These were not conventional cone-shaped volcanoes but great rifts in the Earth’s crust. The rock from the eruptions now forms a vast formation known as the Siberian Traps.

It can also be the Sulphur dioxide causing flash freezing by blocking the Sun for a short time or the more long-lasting carbon dioxide that causes Global Warming and Oceanic stagnation, indicating oxygen poor condition.

The earliest Triassic rocks contain evidence of repeat cycles of oceanic stagnation. These dark, black-colored, pyrite-rich sulphurous rocks contain very few fossils, in contrast to the abundant and diverse fossils in the limestone's just below the extinction level.

The slaughter of life in the sea and on land left a devastated Earth. Pulses of flash warming continued for 5 million years, delaying the recovery of life. Some "disaster taxa" such as Lystrosaurus, a pig-sized herbivore, gained a foot-hold here and it took 10-15 million years for complex ecosystems to become re-established. Evidence on causation is equivocal, with support for either an asteroid impact or mass volcanism, but the latter seems most probable. The extinction model involves global warming by 6^{0}C and huge input of light carbon into the ocean-atmosphere system from the eruptions, but especially from gas hydrates, leading to an ever-worsening positive-feedback loop, that is known as the 'runaway greenhouse'.

Dating the extinction event:

In spite of being long recognized as the biggest mass extinction of all time, and far more significant than the better-known event at the end of the Cretaceous period (the KT event; 65 Million years ago), the end-Permian mass extinction was, until recently, hard to define. First, the Permo–Triassic (P-Tr) boundary has been dated precisely to 251 Million years ago (Million years ago). Second, the Siberian traps, vast volumes of volcanic lavas, have also been dated more precisely than had been possible before, and the peak of

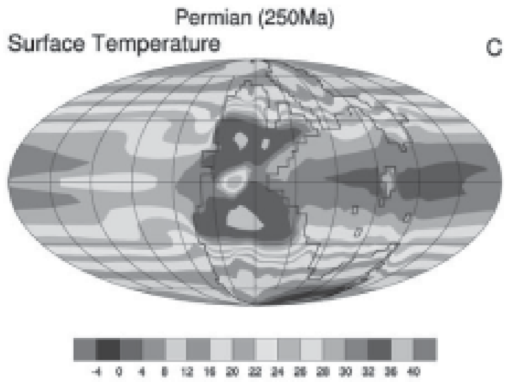


Fig.1 This image shows annual mean surface temperatures in degrees Celsius at the time of the Permian extinction. It is based on a computer simulation generated by the Community Climate System Model at NCAR. Note how the very hot tropical belt extends much further north and south than today, but there are cool polar regions in this model. (Illustration courtesy Jeff Kiehl, NCAR.)

their eruption history matches the P-Tr boundary. Third, extensive study of rock sections that straddle the Permo-Triassic boundary, and the discovery of new sections, began to show a common pattern of environmental changes through the latest Permian and earliest Triassic (253–249 Million years ago). Fourth, studies of stable isotopes (oxygen and carbon) in those rock sections revealed a common story of environmental turmoil. Together, these themes seemed to point to a model of change in which normal feedback processes could not cope and the chemical and temperature balance of the atmosphere and oceans went into catastrophic breakdown.

Proposed mechanisms for the long-term environmental stress and mass extinction :

The large scale mass-extinction at

the end of Permian can be predicted using large scale magmatic eruption events correlating with oceanic anoxia and carbon isotope excursions. Thus about 251 million years ago, suddenly an environmental catastrophe that lead to "Great Dying" began but its effect lasted for several millions of years. There are many causes that have been proposed to explain the Permian mass extinction. The causes are divided up into two main groups: diversity dependent and diversity independent. Diversity dependent hypotheses are new and are not very popular with many scientists but they do make sense. Diversity-dependent factors limit population growth as population sizes get larger. It involves a deterioration of environmental factors such as oxygen, nitrogen, and carbon dioxide, whereas diversity-independent hypotheses, which are more common and widely accepted, involve models that affect all individuals of a species equally and is independent of the number of species present.

We assess the evidence for the Siberian Traps as a primary trigger for the mass extinction at the end of the Permian.

The Siberian continental flood basalt province :

Not without good cause this is recognized as the largest continental flood basalt province, but less than a half of it is now seen at the Earth's surface; the bulk of it is buried beneath thick sedimentary cover. The most obvious outcrop of the Siberian continental flood basalt province (or Siberian Traps) is located on the Siberian craton, a region that has been tectonically stable since

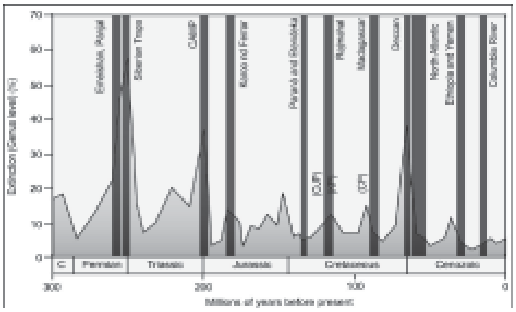


Fig. 2 Extinction rate versus time (continuous line, blue field represent multiple-interval marine genera) compared with eruption ages of continental flood basalts (red bars). Three of the largest mass extinctions, the Permo-Triassic, Triassic-Jurassic and the Cretaceous-Tertiary, correspond with the eruptions of the Siberian Traps, the Central Atlantic Magmatic Province, and the Deccan Traps, respectively.

Precambrian times (Figure 2).

The area of the province preserved on the craton is of the order of 2.5 million km^2, including the region underlain by upper crustal intrusive. The thickness ranges from more than 3 km near Noril'sk and Maymecha-Kotuy at Central Siberia, thinning towards the south and east.

There are four possible

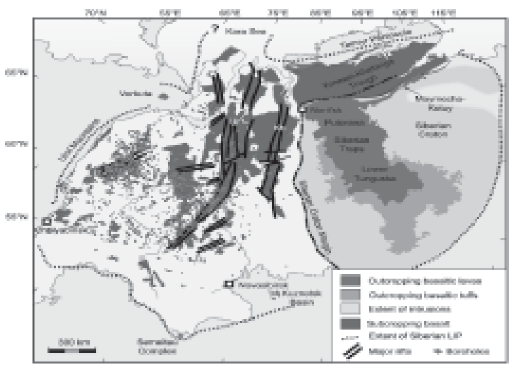


Fig.3 Map of present-day western Siberia, showing the distribution of Permo-Triassic igneous rocks.

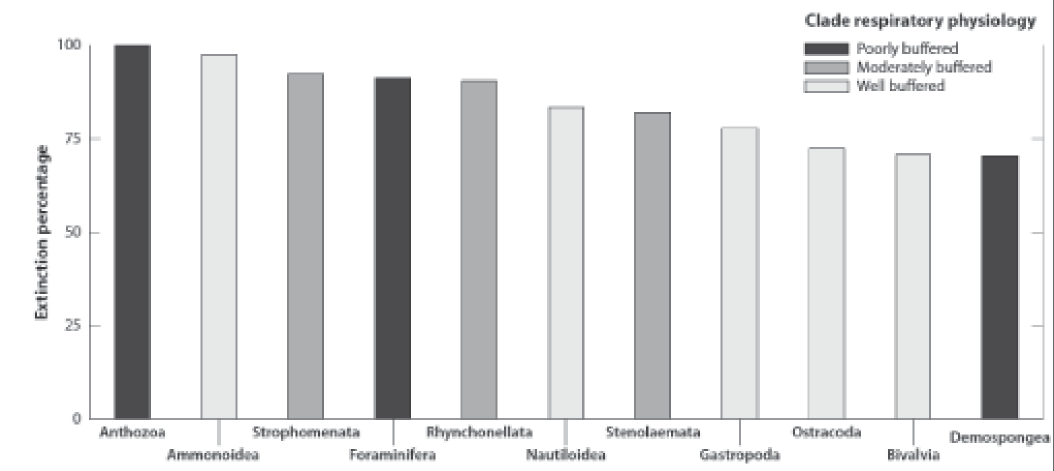


Fig.4 Physiological selectivity of the end-Permian extinction. Clades with poorly buffered respiratory physiology are shaded dark brown, moderately buffered clades are in brown, and well-buffered clades are in light yellow. Invertebrate extinctions are calculated as a raw percentage on the basis of all Changhsingian genera from the Paleobiology Database data; the foraminifers' extinction is also found at a raw percentage...-from Groves & Altiner (2005).

mechanisms through which massive volcanism might be able to cause mass extinctions: a) creation of a dust cloud that reduces photosynthesis and initiates global cooling; b) injection of massive amounts of CO_2 and sulfates is converted to sulfuric acid and reducing the protective ozone shield; c) creation of a thermal anomaly; and d) injection of poisonous trace elements into the atmosphere and oceans.

New 40Ar/39Ar data for basalts from Noril'sk, Lower Tunguska, Taimyr, and the Kuznetsk Basin and from Vorkuta in the Polar Urals confirm that the age of eruption in these regions was also around 250 Ma.

With the presently available age data, it is not possible to determine precisely how long it took to emplace the whole of the Siberian Traps. However, using both U-Pb and Ar-Ar dates in recent paleo-magnetic and radiometric studies of the Deccan Traps, India; it is suggested that the bulk of those lavas in Indian Peninsula were erupted in less than 600000 years. If these estimates are correct, a timescale of less than 1 Ma for the emplacement of the bulk of the Siberian Traps seems realistic.

In this long period, continuous CO_2 emission from volcanic eruption may act as an insulator and initiate a green house effect. McLean [1985] suggested that the buildup of 4-8 fold atmospheric CO_2 results in a failure of primary productivity and decline in the amount of CO2 being sequestered in the deep ocean. This caused global warming, lowering of pH in the Upper Ocean and perturbation of the ecosystem. He estimated that Siberian trap might have contributed 1.8x 10^{18} moles of CO_2 over $\sim$1M.a.

This results that Surface air temperatures were 10–40 ^{0}C warmer than the present-day control simulation at the highest southern latitudes. In the Northern Hemisphere winter land temperatures are 10–20 ^{0}C warmer than the present-day simulation and are more consistent with the paleo-climatic data. The minimum daily mean maximum summer temperatures in the dry subtropical regions are 51^{0}C in some regions, which is 15 ^{0}C higher than simulated present day daily maximum summer temperatures.

Changing environmental conditions across the Permo-Triassic boundary :

The majority of the preserved marine P-Tr boundary sections are located on the continental shelves within the Paleo-Tethys realm, but some are from the Pan- thalassic

Ocean, and several sections are terrestrial. Deep-water sections are rare, because most have been sub- ducted, but a deep water section from the Pan-thalassic Ocean has been preserved in accreted terrains in Japan.

There are several recent overviews of the end-Permian mass extinction event, and the accompanying the eco-logical and the environmental changes. The Permian Period was characterized by a rich faunal and floral diversity which was strongly reduced during the end-Permian extinction events. There is some debate about the number of taxa that became extinct at the end of the Permian, but it is thought that at least 90% of marine species, 57% of all families, and 83% of all genera went extinct. In the marine realm, the benthic communities were particularly affected,

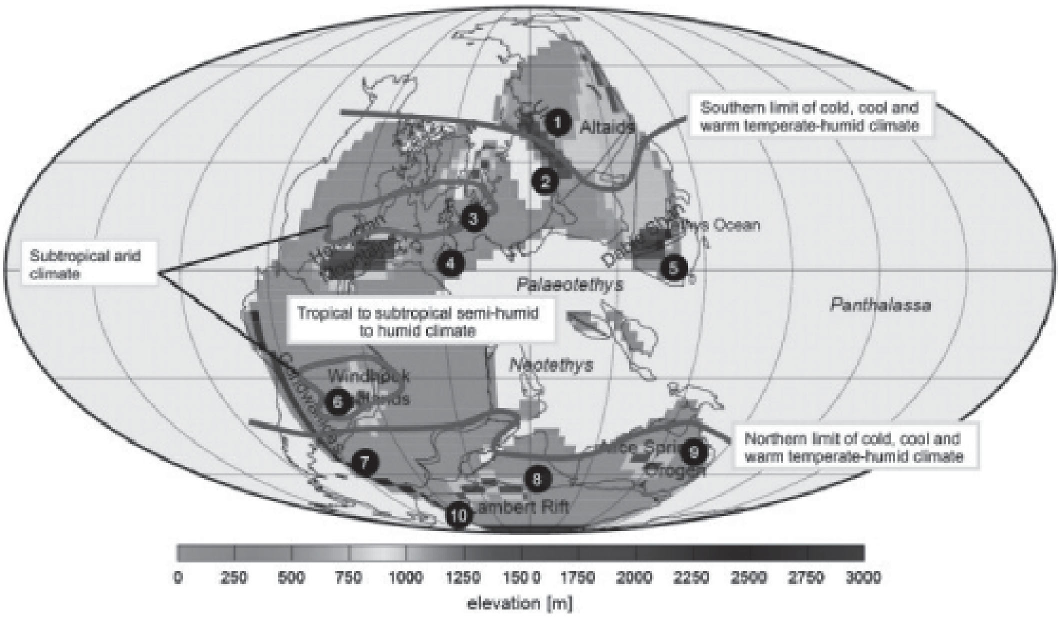


Fig.5 Permian-Triassic Pangaea palaeogeography, with the location of the main P-Tr terrestrial basins and boundary sections indicated, (1) West Siberian/ Kuznetsk Basin, (2) Precaspian/ Urals foreland basin/Russian Platform, (3) Central European Basin, (4) Iberian Basin, (5) South China, (6) Paraná Basin, eastern South America (7) Karoo, South Africa, (8) Satpura/ Raniganj basins, central India, (9) Bowen Basin, western Australia, and (10) Victoria Land and the central Trans-Antarctic Mountains, Antarctica. From Roscher et al. (2011). Late Permian climate zones are generalized from Schneebeli-Hermann (2012)

and on land the variety of insects, tetrapods and forests were diminished considerably. During the late Permian, much of Europe was covered by conifer forests, but these disappeared to be replaced by lycopsids (e.g., *Pleuromeia*) which are small, tree-like mosses. Palynological and palaeosol data indicate the existence of deciduous forests at high latitudes during the latest Permian. Low faunal and floral diversity persisted well into the Triassic, especially at the community level.

A common feature of many P-Tr marine sections is the evidence of oceanic dysoxia (reduced content of dissolved oxygen), anoxia (absence of dissolved oxygen) and, in the most extreme examples, euxinia (presence of reduced sulphur). At the present time, the Earth's oceans are oxygenated to all depths, and anoxia and euxinia are restricted to isolated water masses such as the Black Sea, or to the water trapped within the ocean bottom sediments. However, evidence for oceanic anoxic events (OAE) in the past is, in contrast, frequently found. During an OAE, a large part of the water column is depleted in oxygen and, in extreme cases, only the wind-churned surface waters may become oxygenated. As a result, large volumes of the oceans become uninhabitable to organisms that utilize oxygen for respiration. The observation that so many shallow-water sections were anoxic during the P-Tr transition, and that this anoxia often extended well into the Triassic, indicate that the world's oceans were in the grip of a long-lived OAE: a super-anoxic event. Upwelling of anoxic water onto the continental shelves was probably the main direct cause of the extinction of benthic communities, but there is also strong evidence that the shallow-water anoxic events were diachronous.

Sea-Level change and its impact on life forms

End Permian event of marine rise although often still regarded as an interval of low-stand, much recent work has shown that the end Permian mass extinction occurs during a phase of rapid on-lap and spread of oxygen-poor bottom waters. First identified in carbonate dominated, shallow marine sections of northern Italy and in the shaly basinal facies of Idaho (Wagnall and Hall am, 1992), the P–Tr "super anoxic event" has since been discovered in most P–Tr boundary sections including the oceanic sediments from the accreted terrains of Japan (Isozaki, 1994...). The evidence for anoxia derives from geochemical Authigenic U-enrichment, Chromium-Sulfate plots. Sediment logically abundant pyrite, and paleo-ecological no bioturbation, specialized dysaerobic fauna of *Lingula* and *Claraia*. Only in the slowly accumulated, deep sea sections, is the organic enrichment observed, suggesting that productivity may have been very low. More importantly, the event removed both phosphorus and nitrogen in the marine realm and induced extinction through nutrient deficiencies. On land, extinctions were caused by a drop in atmospheric oxygen of between 10-90% and probable climatic cooling.

Despite the severity of the P–Tr super anoxic event, several workers have suggested that it is not the sole cause of the end Permian extinction because the onset of anoxia either postdates the extinction (Kozur, 1998), or other factors, such as CO_2 poisoning, are more important (Knoll et al., 1996). Perhaps the most convincing case for death-by-anoxia comes from the field, where the demise of Permian marine taxa regularly coincides with the development of oxygen-restricted deposition, (Wignall and Hall am, 1992, 1993; Hall am and Wignall, 1997).

Unfortunately, unlike for the Cretaceous, any oceanic crust, so produced at the end of the Permian has been lost by subsequent subduction-obduction and by continental accretion. Accordingly, it can only be proposed as a plausible speculation (Hall am, 1999), that a major episode of global warming at the end of the Permian was caused by a marked increase in atmospheric CO_2 as a consequence of both sub-aerial and submarine volcanism on a massive scale. With the concomitant diminution in solubility of oxygen in seawater, a tendency towards marine anoxia would be a notable by-product of such volcanism.

Origination rates and nutrient reduction in the Environment.

Several authors have claimed that the drop in diversity was due to the failure of origination, rather than the extinction. They suggested that the formation of Pangaea and the subsequent regression reduced the opportunities of the allopatric speciation and thus their origination rates. This mass decline in diversity reflected a decline in the origination rate during early Triassic which is related to a mass extinction event by many.

Primary producers form the base of the food chain and variations in the abundance of marine phytoplankton may trigger severe repercussions throughout marine ecosystem and connected terrestrial ecosystems as well. Tappan proposed that in Late Permian period, continental topography, climate, oceanic and atmospheric circulation and particularly the declination in oxygen level may result in a gradual reduction in primary productivity.

However, there is little support in favour of the nutrient sequestration on land as it occurs in Carboniferous coal swamps, not in Permian, at the height of the extinction.

Biogeography Concept

The effects of the formation of Pangaea on plant or animal distributions have long been an explanation for the End-Permian Mass Extinction, despite the fact that Pangaea had formed tens of millions of years prior to the extinction and continued to be persisted long into the post extinction recovery period.

There are three hypotheses present surrounding it:

First, a decline in diversity as a result of a reduction in the number of marine provinces; Second, the elimination of the broad continental shelves during the end-Permian regression affecting the spices living area; Thirdly, increasing instability of trophic resources caused by the climatic effect of Pangaea.

Theory of Provinciality and Trophic Resources

This theory, largely developed by Jim Valentine and Eldredge Moore's, was based on the hypothesis that the formation of Pangaea by the closure of Uralian seaway in the later Permian times forced a reduction in sea-floor spreading. Since the depths of the ocean basins are a function of the age of the oceanic crust, a reduction in the rate of sea-floor spreading will allow the mean age of the oceanic crust to increase, increasing the size of the ocean basins. The net effect should be a marine regression that increased continentally and altered climate patterns, which can even disrupt the trophic resources. Specifically, increased seasonality in near-shore should occur as the continents assemble, along with an increase in nutrient supplies and increased competition as endemic biotas are forced into competition as a result of the merging of formerly discrete provinces. Consequently, a global diversity should be lowest when supercontinents exist.

Continental climates and higher seasonality along marine shelves of larger continents will increase the instability of nutrients, primary productivity and other trophic resources. Since resource availability is more uncertain in highly seasonal environments, this along with different other factors may have played a role in the mass extinction.

Concept of Bolides impact

A major bolides impact is consistent with the rapidity and magnitude of the mass extinction, but it does not easily explain the selectivity against physiological traits rather than dietary traits, the evidence for persistent ocean anoxia, or the long-term perturbations recorded by carbon and sulfur isotopes.

Beyond these issues, the geological and geochemical evidence for bolides impact has been strongly challenged. Reports of fullerene molecules trapping helium and argon with extraterrestrial isotopic compositions (Becker et al. 2001) have not been reproduced in independent analyses of the same samples (Farley & Mukhopadhyay 2001) or from additional P-Tr boundary localities (Farley et al. 2005, Koeberl et al. 2004). A subsurface feature off the coast of Australia interpreted by Becker et al. (2004) as an end-Permian impact crater has been similarly challenged on the basis of poorly constrained age (Rennes et al. 2004) and the absence of tsunami-type deposits at the P-Tr boundary in nearby sedimentary basins (Wignall et al. 2004). The unusually pristine condition of meteorite fragments at the P-Tr boundary in terrestrial deposits from Australia (Basu et al. 2003) has raised questions regarding the likelihood that such grains could be preserved unaltered (French & Koeberl 2010). Subsequent attempts to identify additional meteorite grains from the original samples have so far failed (reported in French & Koeberl 2010). There is no positive evidence for an impact at the Permo- Triassic boundary, but since one can never prove that something never happen, the possibility of an extra-terrestrial impact still exists.

Cosmic Radiation Hypothesis

An increase in cosmic radiation from a nearby supernova was advanced by Schindewolf as an explanation of the Permo-Triassic extinction where there is lack of an erosional break at the boundary. He suggested that major magnetic fields and coincident cosmic radiation occurred within the galactic plane. The movement of the earth through the plane at a cycle of 80-90 million years would subject the earth to considerable magnetism and increased cosmic radiation, and an increase in cosmic radiation might kill much of the terrestrial flora and decrease the supply of nutrients to the oceans indirectly causing mass extinction, a possibility hinted by Bramlette (1965).

Global Cooling and Warming Events :-

There is a possibility that a brief episode of global cooling, perhaps involving bipolar high-latitude glaciations, triggered the extinction. But, closer examination shows that the glacial deposits turn out to be of mid-Permian age and apparently represent a final, bipolar pulse of glaciations at the end of Permo-Carboniferous glaciations. There is no evidence of a global cooling at the close of Permian, indeed there is considerably more evidence for warm climates but with a high temperature gradient between the poles and the equator.

Waterhouse (1973) and Dickens (1983) have suggested global warming as the main cause of extinction although with little impact. It is however dismissed with the point that tropical organisms should be able to escape extinction simply by moving towards the poles.

Species-Areas Effects on survive-lance :-

The co-incidence between marine regressions and the major mass extinctions has led the paleontologists' to suspect a connection between the two. They suggested that species diversity on a land is a function of immigration to the island from a continental source, and extinction on the island due largely to competition. Thus, the immigration rate should be a declining function of the number of species on the island and should approach zero when all the species from the source pool have reached the island. As species diversity increases, the extinction rate also raises in response to the competition for the resource areas increases. The equilibrium species diversity will be the point where the immigration rate and the extinction rate are the same. The species area effect was employed to relate changes in the areas of shallow marine seas to species diversity, and particularly to the end-Permian mass extinction.

Mass Death associated with pyroclastic eruption and sulfur eruption:-

There is deep connection between the volcanism and mass extinction. In addition to the boundary clay itself, there are other ash beds at most localities, suggesting repeated volcanism during the end Permian periods. The tuffaceous texture and geochemistry of the boundary clays and the abundant micro-spherules led to the conclusion that the boundary clays represent marine deposition of an altered intermediate-acidic tuff from silica rich volcanism.

Severity and selectivity of the event:-

No major marine invertebrate or protista group escaped the end-Permian extinction unscathed and many invertebrate clades were eliminated entirely. Trilobites, rugose corals, tabulate corals, goniatites, strophomenate brachiopods, blastoids, and rostroconchs occurred for the final time in pre-Permian strata, in many cases immediately below the extinction horizon, or in post extinction mixed faunas. Spiriferid and orthid brachiopods (Class Rhynchonellata) also morphologically complex super family Fusulinoidea, which suffered complete extinction (Groves & Altiner 2005). Radiolarians also suffered major genus-level extinctions (Feng et al. 2007, Kozur 1998), although Paleozoic holdover taxa occur at many sites (Sano et al. 2010) and members of Triassic genera have been found in the latest Permian faunas (Feng et al. 2007, Sano et al. 2010). The end-Permian extinction was particularly severe for reef organisms and ecosystems. More than 70% of sponge genera were lost, a number that may be artificially low owing to homeomorphism of unrelated Permian and Triassic taxa (Flu gel 2002).The complete extinction of rugose and tabulate corals and the appearance and increasing ecological importance of scleractinian corals in Middle and Late Triassic reefs were other key differences between Permian and Triassic reefs (Flu gel 2002). The ecological severity of the extinction was even more pronounced; in the diverse hyper-calcified sponge-microbe reef ecosystems, that collapsed abruptly (Flu gel & Kiessling 2002) and was replaced by microbialite reefs in the Early Triassic (Baud et al. 2007, Kershaw et al. 2012, and Lehrmann et al. 2003).

The end-Permian extinction disproportionately affected certain marine animal clades, a distinction that largely defines the differences between members of Sepkoski's (1981) Paleozoic and Modern faunas. Physiological differences between the two faunas, particularly the varying degrees of stenotype and eurytopy between brachiopods (Paleozoic fauna) and bivalves (Modern fauna), were initially proposed as a potential explanation for the differential severity of the extinction (e.g., Steele-Petrovi´c 1979), although data available at the time did not permit statistical testing. There is no evidence for variation in extinction intensity across environmental gradients. Chen et al. (2011) documented 72–92% extinction among brachiopod genera in six different habitats from near-shore to bathyal regions around Tethyan Ocean. Although the 92% genus extinction in the reef habitat was higher than in other habitats, the among-habitat differences are not statistically significant.

A Scenario for the End-Permian Mass Extinction :-

MURDER IN THE ORIENT EXPRESS was one of the greatest writing of Agatha Christi where the victim, a singularly loathsome man is found murdered in his compartment in the orient express with 12 knife wounds. As Hercules Poi rot listens to the stories of each passenger on the coach, he finds they eliminate one another as the suspects. Despite the abundant and contradictory clues left by the murderer, Poi rot is left with the body with two possible solutions. Either an unknown person entered the train and killed the man and left at night or all eleven passengers and the porter stabbed the man once in retribution for his kidnapping and murder of a baby girl many years back.

The conditions of the Geo-scientists are not very different as a variety of simple solutions that present themselves as possibilities suffer from some important problems.

However, if we think of a world which existed 290 million years ago, we will look out over the terrain in front of us and would think that we are on an alien planet. “One sees volcanoes spewing ash and lava. Beside them is the ocean which is swarming with many different species of echinoderms, bryozoans and brachiopods. As one looks down onto the sea floor, he will be amazed to see the countless number of starfish and urchins. Some animals there can’t even be described and we have no idea even what phylum they belong to. This is a world at its height in diversity of oceanic species. Millions of wondrous species existed at this time in the ocean and most of them will never appear again in Earth’s history. In the blink of eye things now look vastly different. The sky is dark. Oceans are no longer teaming with life. The stench of sulfur, rotting flesh, and plants hangs in the air. The ground trembles under the feet. We feel an intense heat burning our face. If one looks up will see one of the greatest show of force Mother Nature has ever shown. Whole mountains are being thrown in the air. Lava and debris are everywhere. “You ask yourself, what has happened? Will life ever exists on earth again?” [The End Permian Mass Extinction, By: Grant Erickson].

The above maybe what the end of the Permian period could have looked like. Marine life was devastated, with a 57% reduction in the number of families (Sepkoski, 1986) and an estimated 96% extinction at the species level (Raup, 1979). Oceanic life suffered the most but terrestrial life forms were also greatly affected. There was a 77% reduction in the overall number of tetrapod families (Maxwell and Benton, 1987). All major groups of oceanic organisms were affected with the crinozoans (98%), anthozoans (96%), brachiopods (80%) and bryozoans (79%) suffering the greatest extinction (McKinney, 1987). The end of the Permian and beginning of the Triassic periods marked the single greatest extinction event the earth has ever faced.

Current and future trends :-

If the scenario outlined above is correct, then there are some important lessons to be derived. The key issue is the rate at which CO2 was added to the atmosphere during the eruption of the Traps. Even using the longest estimates for the eruption duration of the bulk of the Traps (~2 Ma) geologically rapid accumulation of CO2 in the atmosphere would occur. The controlling factor appears to be the much longer time it takes to geologically sequester carbon dioxide from the oceans and atmosphere; a persistent residue of CO2 remains in the atmosphere, and this is replenished from the oceans until the CO2 in the combined ocean / biomass / atmosphere system has been reduced to pre-event levels. This takes 100’s of ka. Anthropogenic activities are currently releasing about 7 G.t of C to atmosphere by burning of fossil fuels every year, which are at least two orders of magnitude faster than the eruption of a flood basalt province. There are, however, reasons to believe that we are not heading for another Permo-Triassic extinction event. Firstly, the situation at the end of the Permian, and before the eruption of the Traps, was very different from that before our current experiencing in atmospheric chemistry. The atmospheric CO2 concentration was far higher, and the Earth was already in the grips of a major greenhouse event. Forest thrived at high latitudes, there were no substantial polar ice caps, and the oceanic circulation was sluggish. Now we live in a comfortable interglacial period, and pre-industrial CO2 levels were low. Thus, we are currently adding carbon dioxide to a low background, and it is unlikely that the atmospheric CO2 will rise to the levels estimated for the Permo-Triassic boundary. Secondly, the SO2 released by the volcanism fortunately has no counterpart in the present climate change debate. Global anthropogenic sulphur release into the atmosphere peaked at ~68 Mt S (or ~136 Mt SO2) per annum in the 1980's. This is an order of magnitude less than that predicted from a flood basalt eruption. Furthermore, most of this anthropogenic sulphur remains in the lower atmosphere. The closest analogy would be a nuclear exchange, or a major explosive volcanic eruption. Either could cause an artificial winter, but they would be relatively short-lived events (albeit catastrophic for humanity). Whilst we may not experience a Permo-Triassic event, however, it does not mean that the Earth will escape lightly. Even if we cease all hydrocarbon CO2 emissions now, higher levels of atmospheric CO2 will persist for millennia, with consequences for global temperatures, sea level rise, and melting of permafrost and methane hydrates. Understanding the causes of the end-Permian and other mass extinctions is important to evaluating the present-day climate system. Ancient events offer the opportunity to study the full sequence of events associated with rapid climate change and ecosystem collapse, from onset to recovery. However, much more needs to be accomplished. These include more accurate assessment of flux rates of volcanic gases, which in turn require more accurate resolution of eruption volumes and durations.

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Some Useful Techniques To The Study of Carbonate Diagenesis

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Diagenesis is a term used for all the changes that sediment undergoes after deposition and before the transition to metamorphism. This term includes chemical, physical and biological processes.They include compaction, deformation, dissolution, cementation, authigenesis, replacement, recrystallization, hydration, bacterial action, and development of concretions. (Soft-sediment deformation can be included in diagenesis, but not hard-rock folding and faulting).

Diagenesis
- Eogenesis
- Mesogenesis
- Telogenesis

Types of diagenesis (Krinsley, Boggs, 2006)

Diagenesis of Carbonate sediments begins at the sea floor. Depositional and diagenetic processes may go at the same time. This includes six major processes cementation, dissolution, neomorphism, compaction, dolomitization, micritization.Three major diagenetic environments are Marine, Near-surface meteoric and burial.

Diagenesis is important because it is the indicator of changed environmental condition that is Sea level changes and periods of still-stand account for major diagenetic events, as does climate,Diagenesis alters the fundamental characteristics and properties of sediments, which has implications for interpreting their original environment of deposition.Diagenesis alters the porosity and permeability characteristics of sediments, properties that control sediment's potential as a reservoir for oil, gas or water.

Here the discussion is based on**Carbonate Diagenesis**. Uses of staining techniques and ***cathodoluminescence*** have also been discussed with respect to this topic.

Process of staining and etching

Processes of **etching, staining and cathodoluminescence** are important supplements to petrographic (optical) study for this purpose (Krinsley, Boggs, 2006).Staining techniques are cost effective and it help to differentiate between calcite and dolomite. Using the above mentioned techniques , the plates are prepared, to study the genetic and diagenetic interpretations, drawn on the basis of differences in stain colour and luminescence colour in different cement zones. The interpretations hence drawn on the basis of these changes reflect the cementation history of carbonate sediments, the progressive burial history can also be recognized as the sediments makes its journey from meteoric to sea floor to finally deep burial environments. These changes are cumulatively called as "**Cement stratigraphy**" (Evamy, 1969).

Carbonate minerals are stained over a set period of time with alizarin red-S and potassium ferricyanide only if they will react with dilute hydrochloric acid solution, with which the stain is prepared. The rates of solution of carbonates in the acid control the intensity of color development. For calcite, the rate of solution varies with the optic orientation of the section. The speed of carbonate solution is changed if the acid concentration is altered, but only at concentrations of about 0.1 N is the optic orientation of calcite differentiated by the stain. Etching reduces thin section thickness and clarifies rock texture.

Staining with alizarin red-S differentiates carbonate minerals into two groups. Aragonite, calcite, witherite, and cerussite, which dissolve rapidly in dilute hydrochloric acid, are stained, while dolomite, siderite, magnesite, and rhodochosite, which react much more slowly with the acid, remain unstained.

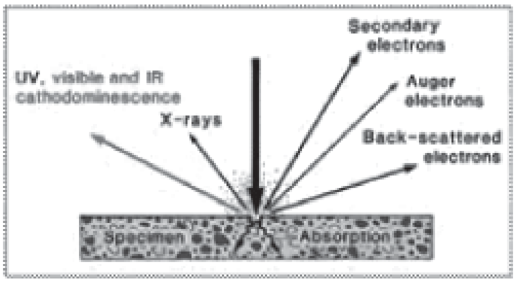
The distribution of ferrous iron, as distinguished by staining with potassium ferricyanide, has proved to be highly significant in the genesis of cements. Ferrous iron can be introduced at any one stage in cementation, or repeatedly, forming zoned patterns. The paragenesis of zoned ferroan cements can be reconstructed after staining. Solution of the more soluble original constituents can sometimes be dated in relation to cementation. Ferroan calcite can be secondary in origin and is usually associated with replacement minerals.

Cathodoluminescence and its use

Cathodoluminescence is the emission of light resulting from the bombardment of materials using a cathode ray (Allan and Wiggins, 1993). This petrographic technique can be an invaluable tool in petrographic studies of carbonate rocks. This technique can provide important information about the complex modification of rock fabrics and porosity.

The visible CL responses are red to orange in color, and their intensity is usually described as non-luminescent, dully luminescent, and brightly luminescent. As a general rule, incorporation of Mn2+ into the calcite lattice stimulates luminescence and the incorporation of Fe2+ quenches or reduces luminescence (Fairchild, 1983; Allan and Wiggins, 1993; Scholle and Ulmer-Scholle, 2003). Qualitative interpretation of CL usually assigns nonluminescent responses to oxidizing settings in which the reduced forms of both Mn and Fe are unavailable for incorporation into the lattices of carbonate mineral precipitates.

Oxidized forms of Mn and Fe are not incorporated into calcite or dolomite crystals. Therefore, there is nothing in these crystals to excite luminescence. Bright luminescence is related to carbonate precipitates with high Mn/Fe trace element ratios, typically as a result of reducing environments during early (near-surface) to intermediate stages of burial diagenesis. Dull luminescence seems to happen where the Mn/Fe trace element ratios are present in carbonate precipitates. Thus, dull luminescence is usually thought to be the result of intermediate to late stages of burial diagenesis. It appears that elements other than Mn and Fe do not have any appreciable effect in enhancing or reducing luminescence (Budd and others,2000).



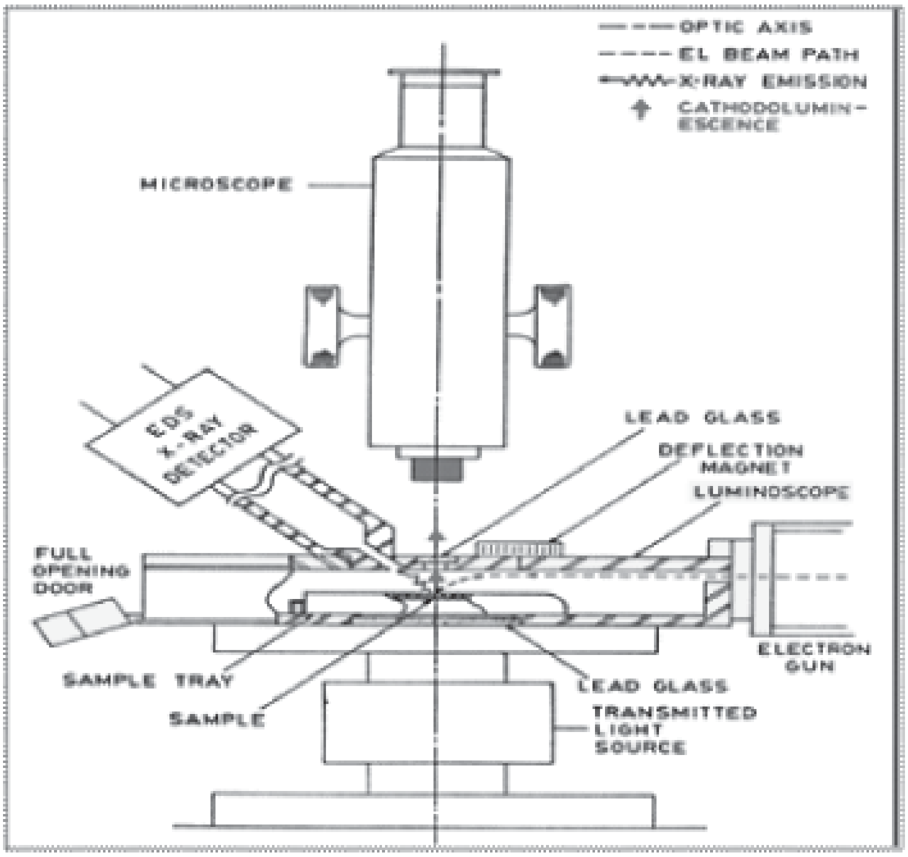
Methodology-

The analysis done in this study was completed using uncovered, polished thin sections,although rock chips and unpolished thin sections could be used. The equipment needed for CL can be installed on almost any polarizing microscope (see Marshall, 1988; Miller, 1988). Operating conditions were generally at 10-12kV accelerating potential, 0.5-0.7 mA of beam current and a beam focused at ~2 cm.

Generalized microscope optical configuration for observing cathodoluminescence.

Uses:

- Fine details of the microstructures within skeletal fragments, such as



The effective concentrations of trace element involved in luminescence is summarized below by-Machel (1979), Gies (1976), Budd et al (2000), Krinsley, Boggs (2000)**:**

Activator	Amount (ppm)	Sensitizer (for all ACTIVATORS)	Amount (ppm)	Quencher (ppm)	Amount
Mn^{2+}	**20-40**	**Pb^{2+} Ce^{2+}**	**10 20**	**Fe^{2+}**	**30,200, but according to boggs, >3000-4000**
				Ni^{2+}	**30-35**
Mn^{2+}	**>1000**	**Pb^{2+} & Zn^{2+}**	**Neither sensitize nor activate CL**	**Self-quenched**	**More the concentration, more**
Mn^{2+}	**1-5**			**Fe^{2+}**	**Very low**
Mn^{2+}	**25-<100**			**Mn^{2+}&Fe^{2+}**	**Sole control on CL intensity at<100**
Mn^{2+}	**<200**			**Fe^{2+}**	**>=100**

brachiopods, bryozoans, and phylloid-algal plates, are more readily visible under CL than with transmitted plane light. In addition, calcite cements that rim leached skeletal grains, as well as early generations of isopachous cements, can be easily seen.

- Some of the cements display a series of concentric bright and dull luminescent bands that represent multiple generations of cementation under varying water chemistries. Such concentrically banded cements are similar to those cements used in calcite cement Stratigraphy within Carboniferous carbonate systems in North America by Meyers (1974, 1978, 1991) and Goldstein (1988, 1991). Finally, CL makes it easier to see the pore outlines and boundaries than under plane light viewing. Thus, it becomes possible to qualitatively interpret how interconnected the remaining pore systems are within this sample.

- Cathodoluminescence imaging was used to examine the details of early, fibrous, marine cements that occur as distinct botryoidal fans.
- Most of these fibrous cements exhibit fairly uniform orange and red luminescence.The blunt to squares ends of several radiating bundles of fibrous cements can be seen. Small,internal dissolution

pores crossing these early marine cements are also more readily visible using CL.

- Cathodoluminescence imaging was particularly useful in identifying the shape and distribution of phylloid-algal plates.
- Cathodoluminescence imaging makes it much easier to see the open (versus cemented) pores and microfractures within this sample.

Cathodoluminescence imaging clearly and rapidly images pore spaces that cannot be easily seen in standard viewing under transmitted, plane-polarized lighting. In addition, the cross sectional size, shape, and boundaries of pores are easy to determine.

Disadvantages of CL (Some geological applications of cathodoluminescence, Virginia T.McLemore et al):

- Most samples, either thin sections or thin slabs, must have at least one polished surface, which adds to preparation time and expense.
- Heating of the sample with the electron beam can cause problems. Some organic-rich samples, such as coal, can volatilize and cause instability in, or even damage to, the CL instrument (Barker and Wood, 1986a). Easily volatilized bonding agents must be avoided. Heating can also cause leakage or stretching of low-temperature fluid inclusions; fluid inclusion work must be completed before CL analyses are done. Relatively unstable minerals, such as some

Luminescence characteristics of carbonate minerals (Krinsley, Boggs, 2006, Hans- G. Machel, 2000) Luminescence controlled by REE's, Iron, Mn^{+2} trivalent REE, activator ions of Fe^{2+} is the principle quencher.

<u>FOR CALCITE</u>

EMISSION PEAK OCCUR		COLOUR
~605-620 nm	Mn^{+2} activated	Orange –Yellow
~590 (605-620) nm		
~550,545,580,600,650, 680,710,760 nm	REE (Sm^{+3},Tb^{+3})	Tb^{+3} shows Green, Sm^{+3} showscream white
<u>FOR ARAGONITE</u>		
~ 540,560 nm	Intrinsic Mn^{+2}	Yellow-Green,Green
<u>FOR DOLOMITE</u>		
570-583		
649-659 nm	Mn^{+2}	Yellow, red
Diagenetic environment		
583-659 nm	Evaporatic	Homogeneous red emission
577-650 nm	Recent evaporatic	Yellow emission
570-649 nm	Non-evaporatic	Yellow-Orange bands
575-656 nm	Hydrothermal Dolomites	Orange-red emission

uranium minerals, can be altered by heating.

Some additional problems encountered with CL include: 1) the quality of the image transmitted through the stage, particularly a high magnification, 2) the need for long-working-distance objective lenses and condensers, and 3) the low-intensity CL image produced in some minerals at the beam energies now available.

Application of cathodoluminescence in determining diagenetic environment

The classification and environmental interpretation of limestones depends upon recognition and identification of these components in thin sections. Cathodoluminescence imaging is a useful supplement to petrographic (optical) study for this purpose.Thediagenesis of carbonate sediments may involve organic processes(e.g., boring and shell breakage by organisms), physical processes compaction and bed thinning, grain breakage), and chemical processes(e.g., dissolution, cementation, neomorphism). Eogenesis begins on the seafloor with organic reworking of sediments, early cementation, neomorphismand possibly dissolution, depending upon environmental conditions. The sediments may subsequently undergo a phase of meteoric diagenesis if a shallow depositional basin fills with sediment toor abovesea level or if sea level falls, exposing previously formed carbonates. Diagenesis in the meteoric zone may include cementation, dissolution, alteration of Mg-calcite to calcite, and neomorphism of aragonite tocalcite. Mesogenesis begins when subsidence eventually brings carbonate sediments into the deep-burial environment where physical processes (compaction and pressure solution) take place and where further chemical changes occur (cementation, neomorphism, mineral replacement, dissolution). Diagenetic effects can continue with late-stage uplift of deeply buried sediment and exposure in the meteoric zone (telogenesis). The CL study of these cements and the genetic and diagenetic interpretations drawn on the basis of differences in the CL characteristics of different zones in cements is referred to as cement stratigraphy. Cathodoluminescence petrography has applications also to study of neomorphic processes such as recrystallization of dolomite.

The cementation history of carbonate sediments may be quite complex given that carbonate cements can be precipitated in seafloor (depositional), meteoric, or deep-burial diageneticenvironments. Carbonate cements may be composed of aragonite, calcite, Mg-calcite (>4% $MgCO_3$ in solid substitution), or dolomite and may exhibit a variety of textural forms depending upon the diagenetic environment.(Sam Boggs Jr, David Krinsley, 2006)

CONCLUSION:

Cathodoluminescence is a common phenomenon in solids minerals that results from complex physical processes after excitation by an electron beam. Cathodoluminescence imaging and spectroscopy are luminescence techniques with widespread applications in geosciences. CL provides the

CEMENT STRATIGRAPHY:

TYPE OF CEMENT	ENVIRONMENT	CAUSE
MENISCUS, PENDANT, OR FIBROUS	SHELF/ METEORIC VADOSE. (oxidizing environment)	$Mn^{4+} > Mn^{2+}$ and $Fe^{3+} > Fe^{2+}$. Hence non-luminescent.
ISOPACHOUS	PHREATIC ZONE (reducing)	$Mn^{2+} > Mn^{4+}$ and Fe^{2+} has less effective concentration to be able to cause any quenching.
BLADED, PRISMATIC, COARSE MOSAIC, EPITAXIAL.	DEEP BURIAL ENVIRONMENT (highly reducing)	$Mn^{2+} >> Mn^{4+}$ and $Fe^{2+} >> Fe^{3+}$. Dull luminescence due to self-quenching by increasing amounts (>1000ppm) of Mn^{2+} and Fe^{2+} related quenching.

information about the real structure of minerals and materials. The close relation between specific conditions of mineral formation, real structure, and the CL properties may provide important genetic information concerning geological and technical processes.

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Mantle Xenolith

Mahasweta Mukherjee, *M.Sc. 1st Year*

At first we have to know what is Xenolith? The term came from ancient Greek word, means “Foreign Rock” . A xenolith is a rock fragment which becomes enveloped in a rock during the latter’s development and hardening. To be considered as a true xenoliths the included rock must be identifiably different from the rock in which it is enveloped.

Mantle Xenoliths are clasts of mantle rocks entrained within magmas and provide important samples of the Earth’s mantle. Normally our knowledge of the mineralogy and chemical composition of the Earth’s mantle is indirectly derived from high-pressure experiments , seismic data , cosmochemical and isotopic constraints. *Mantle xenoliths provides an overview of the lithospheric mantle at the time of their extrusion*. For instance,

1. Xenocrysts of quartz in a silica – deficient lava
2. Diamonds within kimberlite diatremes
3. Spinel peridotite xenoliths found within alkali basalt of Bhuj, Gujrat
4. Garnet peridotite xenoliths are found within lamproite, kimberlites of Andhra Pradesh, Central India.

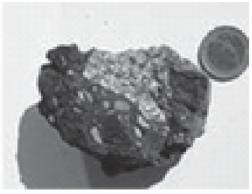
Mantle xenoliths occurs as xenocryst , is an individual foreign crystal included within an igneous body . The majority of mantle xenoliths are ultramafic rocks containing abundant olivine and include lherzolite , harzburgites , wehrlites and dunite . Pyroxenites , basic rocks dominated by pyroxene are also common within basaltic , ultrabasic and alkaline igneous rock. The presence of mantle xenoliths *indicates rapid ascent to prevent settling and suggests the host magma has not been stored in crustal magma chamber* .Mantle xenoliths bearing magmas are generally Primitive magmas.

Re-equilibration of mantle xenoliths during ascent can result in transformation of high pressure phases and partial melting due to decompression. Xenolith may also react with host magma.

How do they occur?

Xenoliths commonly show coarse or porphyroclastic textures or the continuum between the two. At higher differential stresses , coarse texture evolve into porphyroclastic which are defined by the development of smaller fragments of olivine crystals amongst stronger pyroxene, garnet or spinel.

There are different types of xenoliths in different localities. According to *Pearson et al.(2003)* over 3500 mantle xenoliths localities are currently known world over. The location and nature of

many of these occurrences are summarized by Nixon (1987). A s a general rule ,*mantle xenoliths in alkali basalts and nephelinites tend to bespinel facies peridotites whilst kimberlites entrain both spinel and garnet facies peridotites (* Nixon , 1987 ; Harte and Hawkesworth , 1989). The continental occurrence of the xenoliths can be subdivided into three groups on the basis of the crust and tectonic history of the area being sampled -

- Cratonic
- Circum cratonic
- Non - Cratonic

(*information from* ***Journal Geological Society of India Vol.73, May 2009, pp.657,written by*** N.R. KARMALKAR1, R.A. DURAISWAMI1, N.V. CHALAPATHI RAO2 and D.K. PAUL3)

DISTRIBUTION OF XENOLITH OVER INDIA – There are four major Archean cratons in India. All these four cratons contain potassic – ultrapotassic, mafic – ultramafic alkaline magmatic rocks (such as kimberlite, lamproits and lamprophyres and the alkaline rocks i.e, alkali olivine basalt, basanite, nephelinite, melanephelinite). Both kimberlites and lamproites of more than one generation are emplaced into basement gneisses along their boundaries within the Dharwar , Bastar and Bundelkhand Craton (Paul *et al*. 2006). For instance , Kimberlite and lamproit field in Bastar craton , Eastern Dharwar craton and Bundelkhand craton , Alkaline plugs and / lamprophyre dykes in Singbhum craton etc.

Importance – The only direct evidence for the petrology and composition of the very top of the mantle is from xenoliths. Xenoliths in basalts and kimberlites come from the lithosphere or asthenosphere ,contain garnet , plagioclase or spinel peridotite . Garnet , plagioclase and spinel are the dominant Al – containing minerals in the mantle. Each is stable at different pressure regions.

Mantle xenoliths represent part of the earth's upper mantle which has been incorporated into a rising volcanic melt and then subsequently erupted onto the surface . Mantle xenoliths provides a sample direct from the upper part of the Earth's mantle . So , we came to know about the mantle petrology.

Rounded, yellow, weathered Peridotite (green) mantle xenolith within a dark xenolith in a nephelinite lava flow. volcanic bomb from Germany) Kaiserstuhl, SW Germany

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JOURNAL GEOLOGICAL SOCIETY OF INDIA Vol.73, May 2009, pp.657-679

Anisotropy of Magnetic Susceptibility: A case study from Raniganj Basin

Hindol Ghatak, *M.Sc. 2nd Year*

The low field Anisotropy of Magnetic Susceptibility is a great tool for understanding the magnetic fabric orientation in a rock sample. The magnetic foliation is helpful to correlate with structural fabrics in understanding the regional tectonic scenario.

Susceptibility is a function of direction. Studies of anisotropy of magnetic susceptibility have a wide range of application. AMS exceeding 5% is generally observed in rocks with obvious megascopic fabric and values exceeding 10% are rare. Because AMS can be measured more quickly and easily than measuring mineral orientation by optical analysis of thin section, AMS has been used to examine petro fabrics.

Anisotropy of magnetic susceptibility is commonly expressed by comparing magnetic susceptibility values in three mutually perpendicular directions: K_1 = maximum susceptibility ; K_2 = intermediate susceptibility and K_3 = minimum susceptibility . These values describe the magnetic susceptibility ellipsoid. If $K_1 \simeq K_2$ but $K_2 > K_3$, the ellipsoid is oblate(flattened); if $K_1 > K_2$ and $K_2 \simeq K_3$, the ellipsoid is prolate(cigar-shaped). Magnetic susceptibility ellipsoids are usually interpreted as indicating statistical alignment of elongate or platy magnetic grains, usually ferromagnetic grains.

AMS application has been made to sedimentology, igneous processes, and structural geology. Sedimentary rocks and volcanic rocks generally display a slight AMS of oblate susceptibility ellipsoid with K_3 perpendicular to bedding and volcanic flow surfaces respectively. In structural application it used to investigate the pattern of strain. A simplified view is that elongate ferromagnetic grains are passively rotated during straining of rock.

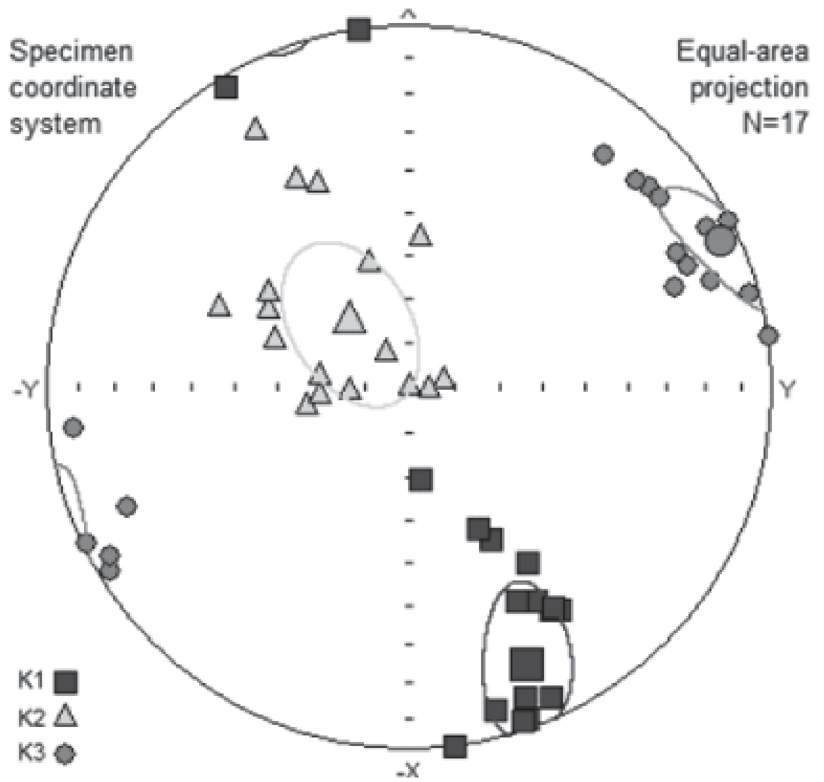
The basic steps involved are collection of oriented block samples following with coring and cutting to bring out specimens of specific dimensions. 15 directional magnetic susceptibility measurements are done with proper data analysis. It is followed by preparation of stereo plots, bi-plots of essential parameters. The attitudes of the lineation and the foliation plane can easily be known. Finally it involves the determination of stress and strain direction and establishment of tectonic movements. Inferences of paleoflow directions can also be drawn in case of sedimentary or volcanic environment.

The basic steps involved are collection of oriented block samples following with coring and cutting to bring out specimens of specific dimensions(i.e2.5 cm diameter and 2.2

cm length). 15 directional magnetic susceptibility measurements are done with proper data analysis. It is followed by preparation of stereo plots, bi-plots of essential parameters. The attitudes of the lineation and the foliation plane can easily be known. Finally it involves the determination of stress and strain direction and establishment of tectonic movements. Inferences of paleo flow directions can also be drawn in case of sedimentary or volcanic environment.

My experiments involved the usage of 117 oriented cylindrical specimens obtained from 25 block samples collected from Koderma region which were representing seven dykes.Kappabridge KLY-2 was used for measuring the magnetic susceptibility of rock specimens and its anisotropy.Its operation is based on measurement of inductivity changes in coil due to rock specimens.In principle the instrument represents a precision semi-automatic auto balance inductive bridge.It is equipped with automatic zeroing and automatic compensation of the thermal drift of the bridge unbalance.KLY-2 has very fast measuring rate and high accuracy and even can measure rock samples with very low magnetic susceptibility. This instrument can be attached with high and low temperature variations of magnetic susceptibility.

From the obtained AMS data measurements, the maximum (K1), intermediate (K2) and minimum (K3) magnetic susceptibility directions along



STEREOPLOT OF AMS DATA (Fig. 1)

with degree of anisotropies were calculated for all the studied dyke samples by using the Jelinek statistics (software provided by Agico, Czech Republic).

Table 1.shows the typical AMS results obtained from one of the studied dykes.

Mean tensor (Jelinek statistics)

N =	17	Dec / Inc	Conf. angles
K1	1.010	157.0 / 18.6	21.0 / 8.3
K2	1.000	317.0 / 70.3	20.4 / 13.1
K3	0.990	64.9 / 6.3	15.2 / 7.1
	Mean	**Average**	**St. deviation**
Km	N/A	1.82E-02	2.73E-03
L	1.010	1.013	0.004
F	1.009	1.010	0.005
P	1.020	1.022	0.005
Pj	1.020	1.023	0.005
T	-0.025	-0.188	0.410
U	-0.030	-0.192	0.409

From the table-1 it could be understood that 17 specimens were measured representing the dyke and K1, K2 and K3 directions along with Lineation (L), Foliation (F), degree of anisotropy (P and Pj) and shape parameters (T and U) were calculated by using the Jelinek statistics. Fig.1 shows the presentation of K1, K2 and K3 directions of all the measured 17 specimens on the stereogram. The average K1, K2 and K3 directions were represented by relatively bigger size Square, triangle and circle respectively. The ovals encircling the mean K1, K2 and K3 directions represent the 95% confidence levels.

The greater circle joining K1 and K2 axes represent the magnetic foliation plane while K3 is the Pole for this defined plane. From the figure it could be noticed that there exists a good grouping of K1, K2 and K3 directions and therefore the magnetic foliation could be defined as NNW-SSE. The magnetic foliation defined from AMS data set was comparable to that of the dyke trend.

Fig.2 shows the relation between

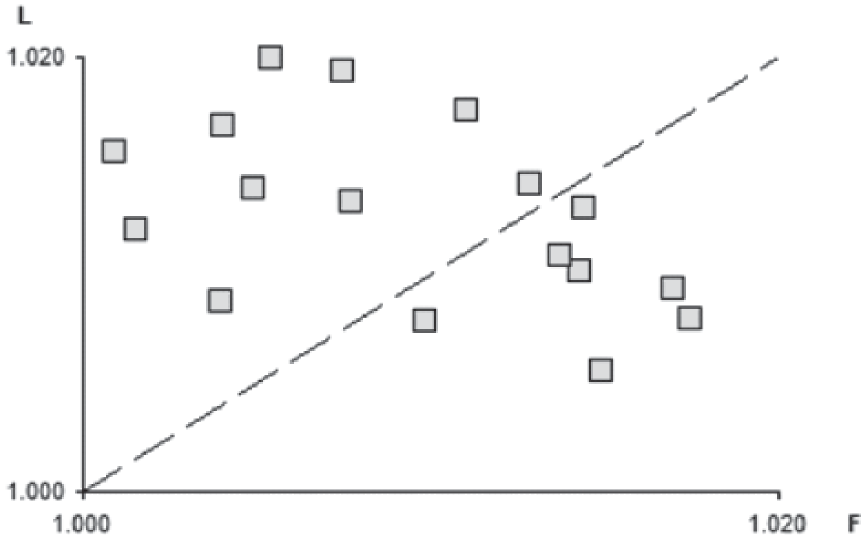


Fig. 2 Lineation to Foliation plot

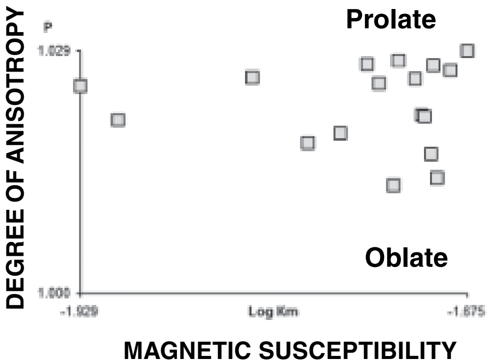


Fig. 3 Degree of Anisotropy to Magnetic Susceptibility plot

the Lineation (L) and Foliation (F). The square symbols above the dotted line represent the Prolate shapes of the magnetic grains, whereas, the symbols below the dotted line show the Oblate shapes of the magnetic grains. From this figure we could observe that there exists more or less equal amount of oblate and prolate shaped magnetic minerals in the samples

Fig.3 shows the relation between magnetic susceptibility (Km) vs degree of anisotropy (P). This figure shows that the observed degree of anisotropy does not depend on the magnetic susceptibility.

Conclusion:

From the generated AMS data sets on the dykes, it was observed that the AMS technique could be potentially used to understand the magma flow directions as well as magnetic shapes (prolate/ oblate) in the rock samples. From The AMS data sets, it was inferred a NNW-SSE directed magma flow directions.

I would like thank Dr. NilanjanDasgupta for introducing me to the topic and Prof. S.K. Patil who guided and taught me throughout this venture.

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Palaeobathymetric and palaeotide level implications of Recent *Uca* mud mounds: a study from Bay of Bengal coast of India

Chandreyee De, *M. Sc. 1st Year*

Introduction

Fiddler crabs *Uca* constitute a large group (about 100 species) of small-sized (maximum 5 cm across), amphibious,marginal marine,burrowing decapod crustacean thriving in soft silty and muddy substrates of sea beaches, brackish inter-tidal mudflats, lagoons, backswamps, mangrove salt marshes, estuaries and creek banks covering West Africa, Western Atlantic, Eastern Pacific and Indo-Pacific coastal regions (Basan and Frey, 1977; Rosenberg, 2001).This genus, represented by *U. marionis* and *U. lactea,*are found to thrive in large number in the Bakkhali beach of west Bengal (Figure 1a) where they produce various types of lebensspuren of which mud moundsproduced in special substrate condition (thick and soft mud layers covered superficially by thin on lap of beach sand layer on either sides of large estuary mouths) in the upper intertidal zone are conspicuous. These mud mounds are the main concern of the present study.Field work was carried out to study the Bakkhali *Uca* mud mounds in terms of their physiological, bathymetric and tide level controls to interpret their fossilized counterparts in rock records.

Burrowing life habits of *Uca*

Mud-loving nature and amphibious life habits control their zoogeographic distribution over moist, muddy and mangrove-vegetated upper intertidal zone all along the Bay of Bengal coast. Within their habitat zones they construct I- shaped simple vertical burrows (3-30cm long), globular feeding pellets, self-crossing trackways, resting traces, distinctive mud chimneys and mounds depending on their physiological needs and surrounding sedimentary environments. Being amphibious, they require alternate spells of subaqueous and aerobic respiration that they perform with specially developed gill structures. Amphibious crabs can manipulate and attain constant gas exchange through gill ventilation and oxygen extraction both in water and air by gill leaflets and branchial lining (acts as lung) respectively (O'Mahoney and Full, 1984).Thus, they require both subaqueous and aerial conditions for sustaining their life in a constructed burrow system. The equilibrium between physiological needs and burrowing mechanisms is attained by extending the burrow base down to a level where capillary accumulation of water at burrow base allows subaqueous respiration by gill moistening and by raising the burrow tubeto open air for aerial respiration and avoidingburrow inundation and collapse. In upper intertidal zone where very shallow

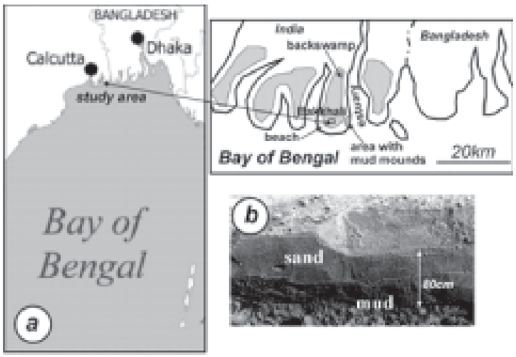

Fig.1 Location of the study area (Bakkhali beach) and *Uca* mud moundsin the Bay of Bengal coast (a); dissected beach profile showing special substrate condition where soft mud layer is superficially covered by beach sand (b).

inundation occurs regularly, the burrow opening is raised above sediment-water interface through construction of either sediment chimneys if substrate sediment is rigid or mud mounds when substrate sediment is soft.

Characterization of Bakkhali *Uca* mud mounds

Opportunistic burrowing activity by these two species and selective exploitation of buried soft mudground under thin veneer of modern beach sands (Figure 1b) around estuary mouth upper intertidal flat of Bakkhali beach (Figure 1a) have produced conspicuous conical mud mounds (simple and compound). The mechanism of formation of mud mounds, as observed live in field, involves shallow vertical burrowing (10-22cm long) through the surficial sand cover down to soft mud layer by *Uca* (Figure 2a) and oozing out of burrow base mud slur around the burrow openingsunder dual effects of substrate pressure and biological force. This mud layer is lateral extension of palaeomudground or palaeoforest exposed in proximity (Figure 2j). From field data the following characterizations are made.

1. Morphologically the mud mounds grade between two distinctive end members: simple (a single cone with one apical burrow opening, individually dwelled, Figure 2c) and compound (a larger cone composed of multiple smaller cones each with one apical opening, communally dwelled, Figure 2d). At places the mounds are represented by conical heaps of semi-rigid mud pellets or lumps. In permanently exposed supratidal areas tall (1-5cm long) mud chimneys (Figure 2b) are produced instead of mud mounds. The forms of burrow mouth features, thus, depend on rigidity or moistness of subsurface sediments.

2.The mounds occur in clusters (Figure 2e) over slightly undulated upper intertidal flat with spatially visible differences in population densities [15-20/100 sq.m in higher subaerially exposed ground dominated by simple mounds (Figure 2f-g) vs. 40-45/100 sq.m in lower inundated ground dominated by compound mounds (Figure 2h-i)]. Thus, ground elevation or calibrated depth of tidal inundation controls the distribution of mound types as well as their population density.

3. Mound heights are strictly controlled by depth of water as revealed by the plots of mound height vs. depth of tidal inundation for 182 mounds (Figure 3). The plots define two distinctive fields: compound mounds with greater heights and depth of water and simple mounds with smaller heights and lesser depth of water or exposed

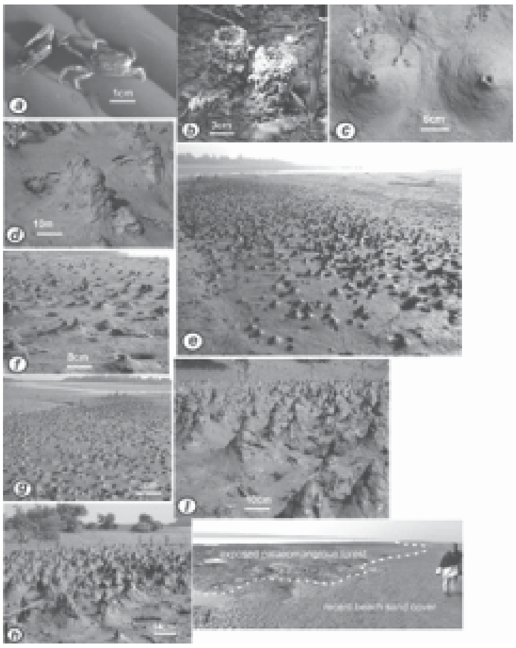

Fig.2 The crab *Ucamarionis* (a); burrow-head chimneys produced by *Uca* (b); simple*Uca* mud mound (c); compound *Uca* mud mound (d); a population of mud mounds in the upper intertidal zone: note height difference (e); two different populations of simple mounds (f, g); two different populations of compound mounds (h, i); outcrop of ancient mudground or palaeoforest in the Bakkhali beach (j).

substrate.This suggests a direct positive correlation between mound heights and water depth, i.e. a bathymetric control. The plots also suggest that compoundandsimplemoundsmaintain their heads above the tidal water level. Most of the simple mounds occur in un-inundated part. This bathymetric controljustifiestheir amphibious life habits and gill respiration requirement.Moreover, the average slope of the plane containing the mound bases closely corresponds to that of the upper intertidal flat.

4. These mud mounds have considerable preservation potentiality as evidenced by theirmass burial under the on laps of beach sand sheets in the Bakkhali area and occurrences of their lithified analogues in post-Jurassic sediments, for example, centimeter scale mud and sand mounds, chimneys and conical pellet heaps in the Quaternary back-reef mudflats of Aldabra Atoll, Taiwanian tidal mudflats, intertidal carbonate sandflats of Bahamas and Miliolites of Saurashtra, India (Dörjes, 1978; Chakraborti and Baskaran, 1989; Curran and Martin,2003). It is important to note that these structures are grossly attributed to crustacean burrowing, reef building and microbial buildupwithout any reference to their makers, palaeobathymetric and palaeotide level implications.

Implications of the Bakkhali *Uca* mud volcanoes

Following the basic principle "Present is the key to the past", the presented morphological, bathymetric and tide level characteristics of *Uca* mud mounds can be confidently applied to their ancient analogues in the following ways.

1. The characterizations revealed can be utilized for ready recognition of ancient *Uca* mud mounds and burrows from the similarities in burrow shape and size and associated burrow-head conical mud mounds in simple and compound modes preserved within intertidal facies. On the basis of these criterions many of the Quaternary mud mounds of Bahama can now be attributed to *Uca* as producers.The crustacean mud mounds of the Pleistocene undisturbed Miliolite

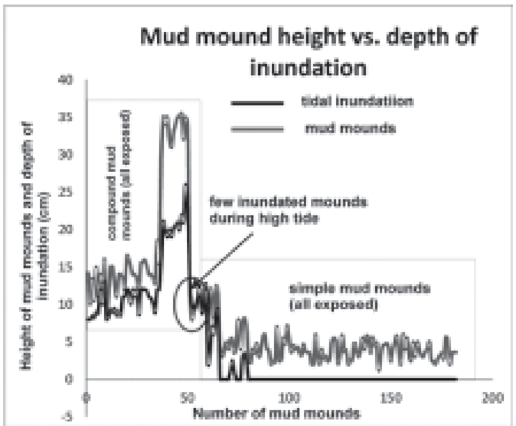

Fig.3 Height vs. depth of inundation plots for 182 mounds, note two distinctive large fields (marked by boxes) - compound mounds with greater heights and depth of inundation (left) and simple mounds with lesser heights and depth of inundation, some are above high tide level or subaerially exposed (right), also note a narrow field in between where some mounds are submerged and hence abandoned or collapsed.

Limestone of Saurashtra coast now occurring at 30-35m above the present sea level suggest earlier high sea stand.

2. The mounds define very preciously the upper intertidal zone and upper palaeotide level in an ancient beach profile. Their lateral extension traces the palaeocoastline and hence basin configuration. These know-hows are essential requirement in basin analysis and oil exploration.

3. The variation in mound heights is the direct reflection of palaeobathymetry and hence suggestive of palaeobeach slope and ancient land-sea positions.

4. Ancient mud mounds covered under on-lapped sand beds and off-lapped clay-silt beds correspond to a transgressive and regressive sequence respectively. These relationships can also be verified from spatio-temporal shift of the ancient *Uca*mound ichnozone in rock sequences.

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ভূতাত্ত্বিক দৃষ্টিভঙ্গিতে আর ই ই

অর্কজ্যোতি সাহা, দ্বিতীয় বর্ষ, স্নাতক

REE বা Rare Earth Elements শুনেই মন ছুটে যায় ক্লাস টেনের সেই বইয়ের পর্যায় সারণীর পাতায়। মনে পড়ে যায় স্যারের বোঝানো 3 বা IIB গ্রুপের কথা। কিন্তু এর সাথে ভূতত্ত্বের সম্পর্ক কী?

বিংশ শতকের শেষার্ধে বিভিন্ন সামগ্রী তৈরিতে REE-এর ব্যবহার শুরু হয় এবং সেই সব সামগ্রী তথা REE-এর চাহিদা উত্তরোত্তর বাড়তে শুরু করে। খোঁজ শুরু হল REE খনির। এই কাজে এগিয়ে এল ভূতত্ত্ববিদেরা। সেখান থেকেই REE এর ভূতত্ত্বের যাত্রা শুরু।

REE কী? পর্যায় সারণীর 3 বা IIIB গ্রুপের অন্তর্ভূক্ত ১৭টি মৌলকে একসাথে REE বলা হয়। ইট্রিয়াম, স্ক্যান্ডিয়াম সহ ১৫টি ল্যান্থানাইড (ল্যান্থানাম, সেরিয়াম, নিওডাইমিয়াম, প্রমেথিয়াম, সামারিয়াম, থুলিয়াম, লুটেশিয়াম ইত্যাদি)। এরা প্রত্যেকেই ধাতু হওয়ায় এদের Rare Earth Metal-ও বলা হয়। শিল্পক্ষেত্রে অক্সাইড হিসাবে ব্যবহৃত হয় বলে এদের Rare Earth oxideও বলে।

REE এর ব্যবহার :- আমেরিকা যুক্তরাষ্ট্রে ২০১২ সালে ব্যবহৃত REE এর পরিমাণ দেখে এর ব্যবহার সম্পর্কে একটা ধারণা করা যেতে পারে। REE অনুঘটক হিসাবে বহুল ব্যবহৃত। এছাড়া সংকর ধাতু বা ধাতুবিদ্যায়, কাচ পালিশ করতে, স্থায়ী চুম্বক তৈরিতে REE প্রচুর পরিমাণে ব্যবহৃত হয়। REE ধাতু বা সংকর ধাতু হিসাবে প্রতিদিনের ব্যবহার্য, যেমন মোবাইল, ব্যাটারি, ডিভিডি, কম্পিউটার মেমারি ইত্যাদিতে ব্যবহৃত হয়। এছাড়া প্রতিরক্ষার নানা সামগ্রী, যেমন রাতে দৃশ্যমান চশমা, ছোট আগ্নেয়াস্ত্র, ওয়াকিটকি জাতীয় পদার্থ, GPS যন্ত্র, প্রতিপ্রভ বাতি, লেসার ফাইন্ডারস ইত্যাদি তৈরিতে REE গুরুত্বপূর্ণ ভূমিকা পালন করে।

REE Usage in percentage

অনুঘটক	৬২
ধাতুবিদ্যা ও সংকর ধাতু	১৩
পালিশ	৯
চুম্বক	৭
ফসফরাস	৩
অন্যান্য	৬

REE কি সত্যিই বিরল? নামে Rare শব্দটি থাকলেও এরা সত্যিই পৃথিবীতে বিরল নয়। এদের মধ্যে সর্বনিম্ন পরিমাণে ভূত্বকে উপস্থিত থুলিয়াম, লুটেশিয়াম-ও সোনার থেকে ২০০ গুণ বেশি পরিমাণে পাওয়া যায়। এছাড়া সেরিয়াম, ইট্রিয়াম, ল্যান্থানাম প্রভৃতি মৌলগুলি প্রধান ধাতু যেমন দস্তা, নিকেল, ক্রোমিয়ামের থেকে সামান্য বেশি পরিমাণে ভূত্বকে উপস্থিত। REE ভূত্বকে গড়ে ১৫০ থেকে ২০০ ppm পরিমাণে থাকে, যেখানে তামা, দস্তা প্রভৃতি ধাতুগুলি কেবল ৫৫ থেকে ৭০ ppm পরিমাণে থাকে। কিন্তু এদের খনি বানানো খুবই কঠিন কাজ। কারণ REE, আকরিকে এত কম আয়তন পরিমাণে থাকে, যা থেকে ধাতু নিষ্কাশন অত্যন্ত ব্যয়সাপেক্ষ ও দুরূহ ব্যাপার।

REE এর উৎস ঃ REE প্রধানত Alkaline rocks, carbonatite নামক আগ্নেয় শিলায় পাওয়া যায়। এছাড়াও Placer deposit-residual deposit-এ; যা আগ্নেয়শিলার আবহবিকারের ফলে সৃষ্টি হয়; তাতেও REE উপস্থিত। এছাড়া পেগমাটাইট, সামুদ্রিক ফসফেট প্রভৃতিতেও REE মেলে।

১) বিভিন্ন শিলার আংশিক গলনের ফলে Alkaline rock তৈরি হয়। বিজ্ঞানীদের মতে, যেসব মৌল আকার, আকৃতি ও গলনাঙ্কের উপর নির্ভর করে সাধারণ শিলায় থাকতে পারে না, তারা Alkaline rock-এ স্থান পায়। তাই এরা সাধারণ Zironium, Niobium, REE ধারণ করে থাকে। এই ম্যাগমা যখন ওপরে ওঠে তখন নানা ভৌত কারণের ফলে মৌলগুলি পৃথক হয়ে যায়। ফলে এদের আলাদাভাবে শনাক্ত করে ধাতু নিষ্কাশন সম্ভব হয়।

২) শিলায় আবহবিকারের ফলে সৃষ্ট পলল নদীতল, সমুদ্রতল, বদ্বীপে জমা হতে পারে। ক্ষয়ের ফলে বেশি ঘনত্ব বিশিষ্ট মৌল (সোনা) গুলি একস্থানে জমা হলে তাকে Placer deposite বলে। তেমনি monzonite যেহেতু REE-এর একটি প্রধান উৎস তাই এর placer desposit এ REE পাওয়া যায়।

৩) নিওবিয়াম, ইট্রিয়াম ইত্যাদি মৌলগুলি কোথাও কোথাও পেগমাটাইট গঠনে সাহায্য করে। এরা granitic introusion-এ বাইরের দিকে থাকলেও খননযোগ্য নয়, কেবল নমুনা সংগ্রহ করা হয় এখান থেকে।

৪) ক্রান্তীয় জলবায়ুতে শিলার গভীর আবহবিকারের ফলে ল্যাটেরাইট গঠিত একটি নির্দিষ্ট Soil profile দেখা যায়। ভারী মৌলগুলির Residual deposit-এ থেকে যাবার জন্য এটা গঠিত হয়। এভাবেই আয়ন শোষণ করে REE আগ্নেয় শিলা থেকে চুঁইয়ে চুঁইয়ে REE সমৃদ্ধ আকরিক তৈরি করে যা থেকে অর্থনৈতিক ভাবে খনি খনন সম্ভব।

৫) এছাড়াও লৌহ-অক্সাইড, তামা, সোনা আকরিকগুলি অন্য আকরিকগুলির থেকে সামান্য আলাদা হয়ে থাকে। এতে REE পাওয়া গেলেও তা নিষ্কাশন পদ্ধতি বা REE সম্পর্কে বেশি তথ্য জানা সম্ভব হয়নি।

এছাড়াও কার্স্ট বক্সাইড, সামুদ্রিক ফসফেট-এ REE পাওয়া গেলেও নিষ্কাশন পদ্ধতি এখনও অনাবিস্কৃত।

REE নিষ্কাশনের সমস্যাসমূহ :- ভূত্বকে প্রচুর পরিমাণে REE পাওয়া গেলেও এর ধাতু নিষ্কাশন পদ্ধতির জটিলতার কারণে বিজ্ঞানীদের নিচে বর্ণিত নানান অসুবিধার সম্মুখীন হতে হয় :-

১) প্রায় সব ধাতব আকরিকে পর্যাপ্ত পরিমাণে ধাতু উপস্থিত থাকে, যেমন Sphalerite-এ দস্তা। কিন্তু REE আকরিকে পর্যাপ্ত পরিমাণে ধাতু থাকে না বলে এর থেকে ধাতু নিষ্কাশন ব্যয় সাপেক্ষ।

২) কোন REE ধারণকারী আকরিকে অনেক সময় তেজস্ক্রিয় পদার্থ মিশে থাকে। তাই এর খনি খনন ক্ষতিকারক ও কষ্টসাধ্য হয়। খরচ সাপেক্ষ হলেও এইরকম আকরিক থেকে নিষ্কাশন সম্ভব হয়েছে।

৩) আকরিকের বিভিন্নতার কারণে কোন সাধারণ প্রক্রিয়ায় REE ধাতু নিষ্কাশন সম্ভব নয়। ফলে বিভিন্ন স্থানে বিভিন্ন আকরিকের নমুনার পরীক্ষানিরীক্ষা করে নতুন ভাবে নিষ্কাশন সময় ও ব্যয়সাপেক্ষ।

REE খনি খনন :- এত সমস্যা সত্ত্বেও বিজ্ঞান REE খনি থেকে নিম্নোক্ত প্রক্রিয়াগুলি দ্বারা REE উৎপাদন শুরু করেছে।

১) প্রথম পদক্ষেপেই হল REE খুঁজে বের করা। ইহা দুভাবে করা হয় ...

i) Greenfield Exploration : এমন কোন Deposit খুঁজে বের করা যেখানে আগে খনন হয়নি।

ii) Brownfield Exploration : যে খনিতে আগেও খনন হয়েছে তার চারপাশেই REE deposit খুঁজে বের করা।

২) ২০১০-এর আগে পর্যন্ত সরাসরি REE খনিতে খনন হয়নি। পৃথিবীর সর্ববৃহৎ খনি চিনের Bayan Obo প্রথমে লোহার খনি হিসাবে পাওয়া যায়। এছাড়াও অনেক REE বহনকারী Carbonatite deposit প্রথমে নিওবিয়াম, ফসফেটের জন্য খোঁজা হয়েছিল।

৩) Deposit খুঁজে পাওয়ার পর এর ড্রিলিং করে প্রাপ্ত structural ও mineralogical data বিশ্লেষণ করে যদি দেখা যায় deposit-টি REE-rich তবে পরবর্তী পদক্ষেপ নেওয়া হয়।

৪) এখন খনি খনন ও ধাতু নিষ্কাশনের পরিকল্পনা করা হয় ও ফল আশানুরূপ হলে সরকারী অনুমতির জন্য দরখাস্ত করা হয়। সরকার পরিকল্পনাটি পরীক্ষানিরীক্ষা করে ভালো ফল পেলে অনুমতি মেলে ও বিভিন্ন ব্যাঙ্ক থেকে ঋণ নিয়ে কাজ শুরুর চেষ্টা করা হয়। একবার ইঞ্জিনিয়ারিং নকশায় খনি তৈরি হবার পর চটজলদি উৎপাদন শুরু করা হয় এবং তা লক্ষ্য মাত্রায় নিয়ে যাওয়া হয়।

৫) যতদিন না deposit শেষ হয় খনন চলতে থাকে ও খনন শেষে সেই স্থান পুনরায় ব্যবহারযোগ্য করে তোলা হয়।

বিশ্বের কয়েকটি REE খনি:-

i) California-র Mountain Pass;

ii) চিনের Bayan Obo;

iii) উটার Lisbon Valley;

iv) Alaska-র Pogo;

v) Australia-র Cawse ইত্যাদি।

দিন যত এগোচ্ছে, REE থেকে তৈরি সামগ্রীর চাহিদা উত্তরোত্তর বেড়েই চলেছে। কিন্তু নতুন খনি খুঁজে বের করা ও REE আকরিক থেকে ধাতু নিষ্কাশন-এর দিক থেকে REE খনি খনন আজও ভূতত্ত্বের সবচেয়ে আলোচিত বিষয়গুলির একটা।

Professor Gouri Shankar Ghatak
18th April 1939 – 5th November 2014

শ্রদ্ধার্ঘ্য
অধ্যাপক গৌরীশংকর ঘটক

গৌতম কুমার দেব

প্রেসিডেন্সী বিশ্ববিদ্যালয় (পূর্বতন কলেজ)-এর আকর্ষণীয় শিক্ষকতার জন্য অবিস্মরণীয় গুটি কয় মাস্টারমশায়ের মধ্যে অন্যতম অধ্যাপক গৌরীশঙ্কর ঘটক খুবই কম সময় অসুস্থ থেকে গত ৫ই নভেম্বর, ২০১৪, ক্যালকাটা হার্ট ক্লিনিক ও হসপিটালে শেষ নিঃশ্বাস ত্যাগ করেছেন। অধ্যাপক ঘটকের স্মৃতিতে এই শ্রদ্ধার্ঘ্য লিখতে বসেই মনে পড়ল ভূতত্ত্ব বিভাগে নিজের ভর্তি হওয়ার এবং কলেজে প্রথম দিনের কথাগুলো।

১৯৭৮। টানা ন-দিন ধরে বৃষ্টিতে হাঁটুজল বুকে নিয়ে কলকাতা পারিপার্শ্বিক থেকে প্রায় বিচ্ছিন্ন হয়ে গেল। তারই মাঝে প্রেসিডেন্সী কলেজের ভূতত্ত্ব বিভাগে ভর্তি হলাম। অনিবার্য কারণে ক্লাস শুরু হল পূজোর ছুটির পর, অর্থাৎ নভেম্বর মাসে। প্রথম দিন, প্রথম ক্লাস। শুরু এবং শেষ হল কাঁটায় কাঁটায়। কিন্তু আজ বলতে দ্বিধা নেই, যিনি নিয়েছিলেন তিনি ভূতত্ত্ব বিভাগের আকবর বাদশা হলেও সেই প্রথম ক্লাস আমাদের মধ্যে সেরকম সাড়া জাগায়নি। বসে আছি দ্বিতীয় ক্লাসের জন্য। কারো সাথে কারোর আলাপ আলোচনার সুযোগ তখনও সেভাবে হয়ে ওঠেনি। কিছুক্ষণ বাদেই একে অপরের নাম, স্কুল ইত্যাদি জানার প্রয়াসে গুঞ্জন শুরু হল। প্রায় মিনিট কুড়ি পেরোতেই এক সৌম্য, শান্ত, স্থির, স্মিত মাষ্টারমশায় ক্লাসে এলেন। প্রাথমিক আলাপচারিতার পর বিজ্ঞানের এক abstract শাখা, 'কৃস্টালমিতি'-র সূচনা করলেন। আজও মনে পড়ে, খুবই সামান্য বুঝতে পারলেও, ভাল ডাক্তারের সামনে পৌছেই অনেক রোগী যেমন বেশ সুস্থ বোধ করে, কলেজে প্রথম দিনের দ্বিতীয় ক্লাসে আমরাও মন্ত্রমুগ্ধের মতো ওনার কৃস্টালমিতি-র সেই সূচনা শুনেছিলাম। অবশ্য দ্বিতীয়বার নিয়ম না ভেঙ্গে ঠিকসময়ে ছুটি দিলেন। ক্লাস থেকে বেরিয়েই রুটিন দেখে জানলাম, উনি ছিলেন `GG' অর্থাৎ গৌরীশংকর ঘটক, যিনি অল্প কয়েকদিনের মধ্যেই পরিচিত হয়ে গেলেন, প্রথমে Prof. Ghatak ও পরে সকলের প্রিয় গৌরীবাবু নামে।

১৯৩৯। ১৮ই এপ্রিল, দশ ভাইবোনের মধ্যে পঞ্চম জন হিসেবে গৌরীবাবু জন্মগ্রহণ করেন শহর থেকে দূরে, প্রায় অসচ্ছল এক পরিবারে। পিতার চাকরি সূত্রে নানা স্কুলে পড়াশুনো করে অবশেষে কাঁথি থেকে স্কুল-জীবনের গন্ডি পেরিয়ে এসে প্রেসিডেন্সী কলেজে প্রাক-স্নাতক স্তরে ভর্তি হয়েছিলেন। কিছুদিনের জন্য ইডেন হিন্দু হোস্টেলেও ছিলেন। ছাত্রাবস্থা থেকেই তাঁর ভাষা, ব্যবহার কিংবা আলোচনায় পারিবারিক অসচ্ছলতার ছাপ পড়েনি কখনও। কারণ ভূতত্ত্বে অনার্স (মেজর) নিয়ে স্নাতক ও পরে স্নাতকোত্তর স্তরে পড়াশুনোর পাশাপাশি বিভিন্ন বিষয়ে বিশেষতঃ পদার্থ বিদ্যা ও দর্শনে-এ কৌতূহল, চর্চা ও পান্ডিত্য ওনাকে সদাসজীব করে রাখে। বিজ্ঞান-শিক্ষায় তিনি কখনই পরীক্ষায় ভাল নম্বর পাওয়ার অথবা চাকুরী জীবনে উন্নতির তাগিদে ব্রতী ছিলেন না। বরংচ বিজ্ঞানে প্রক্রিয়াসমূহ এবং বৈজ্ঞানিক বিশ্লেষণের নিয়মাবলী ও যুক্তি, অর্থাৎ এককথায় বিজ্ঞান-দর্শন ছিল তাঁর একমাত্র অভিপ্সিত। হয়তো প্রচার-বিমুখ মানসিকতা অভিমানী গৌরীবাবুর জীবনে বাধ সেধেছিল।

ষাটের দশকে গৌরীবাবু অধ্যাপনা শুরু করেন, প্রথমে বেঙ্গল ইঞ্জিনিয়ারিং কলেজ, শিবপুর-এ ও পরে প্রেসিডেন্সী কলেজে। মাঝে কিছুদিনের জন্য তিনি দূর্গাপুর গভর্নমেন্ট কলেজেও পড়ান। আমি সত্তরের শেষে ও আশীর প্রথমে ওনাকে শিক্ষক হিসেবে পাই। সেই সময় (হয়তো এখনও) অনেকেরই বিশেষ করে মফস্বলের ছাত্র-ছাত্রীদের কাছে প্রেসিডেন্সী স্বপ্ন, প্রেসিডেন্সীতে পড়া স্বপ্নসুখ এবং প্রেসিডেন্সীতে পড়ানো স্বপ্নবিলাস ছিল। আর আমাদের স্বপ্নসমূহের বাস্তবায়নে যাঁরা ছিলেন অগ্রণী তাঁদের মধ্যে অন্যতম একজন গৌরীবাবু। দুর্ভাগ্যজনকভাবে প্রায়ই ওনার দিন শুরু হতো দেরি করে। ফলে শিক্ষকতা ও বিষয়ের প্রতি সুতীব্র টান - দুইয়ের

যোগসূত্রের ফল অন্তত ভূতত্ত্বের ক্ষেত্রে খুব বেশী ছাপার কালি মাখে নি। কিন্তু পাশাপাশি যাদের গবেষণাপত্র সাড়া জাগাত, তাদের অনেকেরই কাজে ওনার অবদান ছিল অনস্বীকার্য। গৌরীবাবুর রাগ করা বা রাগের বহিঃপ্রকাশ হওয়া ছিল দুর্লভ ঘটনা। সময় সম্পর্কে তাঁর এক অযান্ত্রিক চিন্তাধারার জন্য অনেকেরই মাঝে মধ্যে রাগ হতো। কিন্তু আশ্চর্য্যজনকভাবে স্মিত গৌরীবাবুর মুখোমুখী হতেই বাদশা থেকে সান্ত্রী সকলেরই রাগ জল হয়ে যেত। দুপক্ষই যেন নীরব কিংবা প্রসঙ্গ পাল্টে বলতে চাইত, কবি শঙ্খ ঘোষের ভাষায়–

'অনেক কাছে যাব ভেবেই অনেক দূরে এসেছিলাম।'

ব্যক্তি গৌরীবাবুকে ছাপিয়ে ছিল শিক্ষক গৌরীবাবু। অকৃত্রিম সরলতায় কিভাবে তিনি ভূতত্বের মূল বিষয়গুলি বোঝাতেন তার দুটি উদাহরণ উল্লেখযোগ্য। ফিল্ডে পাথর থেকে কিভাবে pyroxene ও amphibole চেনা যেতে পারে। Mineral grain হাতের তালুতে নিয়ে দেখতে হবে, যদি কাঁচের গুলির মতো গড়ায় তাহলে সেটি হবে pyroxene। আর যদি Cylinder-এর মতো গড়ায় তাহলে সেই mineral হবে amphibole। আরেকটি ফিল্ডে তিনি গাছপালার পরিবর্তন লক্ষ্য করতে বলেন। চোখে পড়ে, শাল মহুয়ার জঙ্গল পেরিয়ে এক ন্যাড়া জমি, তারপর অন্য ধরণের জঙ্গল। কারণটা তিনি Remote Sensing-এর মূলসূত্র দিয়ে ব্যাখ্যা করেন, অর্থাৎ Rock Type পাল্টে গেলে গাছপালার ধরণও পাল্টে যায়। ৩ সংখ্যাটির প্রতি সম্ভবত: ওনার অকৃত্রিম ভালবাসা ছিল। Reference Frame বোঝাতে 3 orthogonal axes বিজ্ঞানের প্রতিটি শাখারই ভিত্তিস্তম্ভ। সেই Reference ভিত্তিস্তম্ভ কৃস্টালমিতি পড়ানোর সময় তিনি বুড়ো আঙ্গুল, তর্জনি এবং মধ্যমার সাহায্যে অনায়াসেই ছাত্র-ছাত্রীদের চোখের সামনে তুলে ধরতেন।

এছাড়াও Structural Geology, Ignous Petrology এবং Metamorphic Petrology- ভূতত্ত্বের এই তিনটি শাখার যেকোন সূত্র ও সমাধান তিনি সমান দক্ষতার সঙ্গে বোঝাতেন ও চর্চা করতেন।

B.Sc. 3rd Year-এর Field Work করতে গিয়েছি রাজস্থানের Jhamarkotra। প্রশ্ন কি করেছিলাম সঠিক মনে নেই। উত্তরে বলেছিলেন, Field-এ এসে তিনটে চোখ খোলা রাখতে হবে। প্রথমটি যা দেখছি তার ওপর এবং দ্বিতীয়টি যা পেরিয়ে এসেছি তার উপর নিবদ্ধ থাকা চাই। তৃতীয় চোখ অবশ্যই খোলা রাখতে হবে এই দুই-এর যোগসূত্র খুঁজে বের করতে। পরবর্তীকালে বুঝতে পারলাম, তিনটি চোখের অর্থ – যথাক্রমে তত্ত্ব সংগ্রহ, তত্ত্ব বিশ্লেষণ এবং তথ্য পরিবেশন। অর্থাৎ বিজ্ঞানের যে কোন শাখায় গবেষণার তিনটি মূল উদ্দেশ্য। আসলে আন্তরিকতার সাথে সাথে এক শিল্পী সত্ত্বাও গৌরীবাবুর শিক্ষকতায় বিরাজমান ছিল।

গত 5th November-এ যাত্রা শুরু। এক শূন্য মাঠে এগিয়ে যাচ্ছেন গৌরীবাবু। ঠিক সামনে একটি এবং লম্বভাবে দুপাশে দুটি মোট তিনটি ছায়া থেকে গেল ভূতত্ত্ব শিক্ষকতায়, সমাজসেবায় এবং রাজনীতিতে।

থাকলাম আমরা সবাই। ফের কবি শঙ্খ ঘোষের একই কবিতার শেষ লাইন, 'এবারে ঠিক সহজভাবেই আগ্‌লে নেব নিঃস্বতাকে' পাল্টে বলি– 'এবারে ঠিক বাধ্য হয়েই আগলে্‌ নেব দায়িত্বটাকে।'