ভূ-বিদ্যা

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Presidency University, Kolkata

Editor
Bidisha Dey

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BHUVIDYA

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Errors and omissions, if any are sincerely regretted

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Foreword

We are really proud to bring out the '56th' volume of 'Bhuvidya', the annual journal of the Geological Institute, a student's body of the Geology Department, Presidency University, Kolkata. Students of this department under the aegis of the Geological Institute pursue various academic activities throughout the year and Bhuvidya serves as the platform in their career to tackle scientific problems and publish their thoughts. It helps encouraging young minds in addressing critical issues in the discipline of Earth science that eventually help in enrichment of this journal as well as shaping up their future. I hope this more than hundred year old organization run by students, will continue its legacy and remain a platform for innovative minds of future geologists for years to come.

It is an important juncture that we are witnessing the transformation of nearly two hundred year old premier institution of India, the erstwhile Presidency College to a newly born university. This transformation ushers in a great deal of responsibility on the teachers, students, staff and alumni of this Institute. Our alumni through the Geological Institute can play pivotal role in such transformation by actively participating in formulation and execution of short-term and long-term plans. And collectively we could strive for excellence through developing world-class infrastructure, best quality teaching, and state-of-the-art research in this premier Institute.

Finally I am grateful to our fellow student members of the Institute and to our teachers for their prolonged effort and endeavour that made publication of our Journal Bhuvidya possible overcoming all odds.

22nd December 2015

Gautam Ghosh
President
Geological Institute

সম্পাদকীয়

জিওলজিকাল ইন্সটিটিউট এর বৈজ্ঞানিক মুখপত্র ভূবিদ্যার ৫৬ তম সংখ্যা প্রকাশিত হল। এই প্রকাশনা এবার পদার্পণ করল আশিতম বর্ষে। আগামী বছর ২০১৬ সালে আমাদের বিশ্ববিদ্যালয়ের ও আমাদের বিভাগ যথাক্রমে ২০০ বছর ও ১২৫ বছরে পা দিতে চলেছে।

সুদীর্ঘ আশি বছর ধরে, ১৯৩৬ থেকে, এই পত্রিকা ভূতত্ত্ববিদ্যার ছাত্রছাত্রীদের উৎসাহিত করে এসেছে মাতৃভাষায় বিজ্ঞানচর্চা করতে। যদিও বাংলায় লেখার প্রবণতা ক্রমাগত কমেই আসছে, আশা করি আগামী দিনগুলিতে আর্ন্তজাতিক স্তরে এগিয়ে যাওয়ার সাথে সাথে, মৌলিক বৈজ্ঞানিক আলোচনাসমূহ বাংলাভাষাতেও এই পত্রিকাতে স্থান পাবে।

একটি আনন্দের খবর, আমাদের বিভাগীয় অধ্যাপক ও প্রাক্তন বিভাগীয় প্রধান জয়দীপ মুখোপাধ্যায় "INSA TEACHERS AWARD 2015" এর সম্মান এ ভূষিত হয়েছেন। তার জন্য আমরা সকলেই গর্বিত।

জিওলজিকাল ইন্সটিটিউট এর সমস্ত সদস্য, এই বিভাগের প্রাক্তন ও বর্তমান শিক্ষক ও ছাত্রছাত্রী, যারা আমাদের পথ চলার সঙ্গী, তাদের জানাই আন্তরিক ধন্যবাদ। আগামী দিনে সবাইকে ইন্সটিটিউটের বিভিন্ন কার্যকলাপের সাথে আরও বেশি জড়িত থাকার জন্য আহ্বান জানাই, আশাকরি আগামী দিনেও এভাবেই আরও এগিয়ে নিয়ে যেতে পারব আমাদের এই ইন্সটিটিউট ও বিভাগকে।

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IS KOLKATA SUBSIDING?

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Honorary Scientist, Indian National Science Academy

Several incidences of subsidence of various dimensions have been reported from different parts of Kolkata in recent times. The first and most significant was the subsidence in patches of the Dhakuria flyover bridge which made the road highly bumpy, obstructing flow of traffic over this busy stretch. Elaborate grouting process was undertaken to repair the damage. A few days after the initiation of the repair process, a sudden sagging of a part of the footpath was noted on the western side of the Gariahat Road South near Jodpur Park. Incidences of subsidence and collapse have now become a regular feature, reported from different parts of the city. Whatever may be the cause, some depressed (or subsided) areas are known over a long time in the central and southern parts of the city, which get waterlogged during rains needing pumping to drain out the rain water. A very significant instance of slow subsidence is recorded over about 5 decades in the Ballygunge Science College building in south Calcutta. So much so is the subsidence that the ground floor block of the Department of Geology virtually looks like a dark cave.

The incidence of subsidence in and around Kolkata is not new. Geomorphologically, the Kolkata topography shows highs and lows between about 17 m near the eastern bank of the River Hoogly to 2/3 m in different parts of the city. Kolkata surface contour shows that the city has a downward slope towards East. The most of the low-lying areas lying out skirts of the norteastern and eastern parts of the city of Kolkata, that includes a part of the Sector V of the Bidhan Nagar (Salt lake). On such is the tourist spot at Nalban, a vast water body. The cluster of the low lying areas which remains submerged during most part of the year is known as East Calcutta Wetlands. The East Calcutta Wetlands were designated a “wetland of international importance” under the Ramsar Convention on August 19, 2002. In view of that these wetlands are now known as the Ramsar Lakes of Calcutta. The wetlands cover 125 square kilometers, and include salt marshes and salt meadows, as well as sewage farms and settling ponds. The wetlands are used to treat Kolkata’s sewage, and the nutrients contained in the waste water sustain fish farming as well as agriculture.

Bhuvidya Barring some low-lying areas within the city limit, the average land elevation over the Kolkata area is between 7 and 10 m (amsl). By contrast, the average elevation in large parts of East Kolkata Wetlands is between 0 and 1 m amsl. In general the western part of the city near the east bank of the River Hoogly represents the higher parts of the city.

The low lying wetland areas did not have the same topography since the beginning of the formation of the lower deltaic region. Studies indicate that this area is slowly subsiding. The estimated subsidence rate is reported to be 13.53 mm/year.

Another study in the East Kolkata region suggested total estimated subsidence near Tangra area is 32.864 cm in 44 years between 1956 to 2000. This works out a subsidence rate of 7.47 mm/year. The total estimated subsidence at Baguiati during the same time interval is 33.11 cm. Since this entire region is more or less uniformly subsiding, and the rate being very slow, very little visible ground crack or collapse of building or structure has been reported till now.

One of the latest space-based techniques used for measuring sub-centimetric ground displacement is the 'Differential Synthetic Aperture Radar Interferometry' (D-InSAR), which is used to assess the potential land subsidence phenomenon of Kolkata. The survey indicated occurrence of a thick surface clay layer with an average thickness of ~40 m and above. This raises a question on the land subsidence phenomenon in Kolkata city. At this juncture, the D-InSAR-based study is likely to help in ascertaining the actual land subsidence scenario around Kolkata and its environs. Preliminary studies made in and around Machhua Bazar, Calcutta University, and Raja Bazar Science College, indicated active subsidence of 5 to 6.5 mm/yr during 1992–98 period.

Unlike Kolkata, the incidence of collapse and destruction of buildings and other structures in and around Dhaka (Bangladesh) has by now taken a disastrous proportion. Severe building collapse and damage to life and property in the Dhaka region is far more extensive than that of Kolkata. The blame for most of the building collapses invariably go to bad construction both in planning and execution. But in certain instances the building collapses could not be assigned to constructional defects but to the land subsidence.

The rate of subsidence obtained from drill-hole data suggests that the area around Dhaka is subsiding at a rate of 2.0 cm/year. Data using D-InSAR technique indicated land subsidence of 0 to >10mm/yr in Dhaka, and from 0 to >18 mm/yr in regions, outside of the city. The lowest rate appears primarily in Madhupur Clay and the highest rate in Holocene organic-rich muds. The frequency in the incidences of collapse of buildings around Dhaka is a clear indication of much higher rate of subsidence.

Dhaka and Kolkata are not the only two areas where land subsidence is noted. We will have to look into the features in a bigger geological perspective to understand the cause of land subsidence in these highly urbanized areas. Both the cities have grown over the youngest and largest

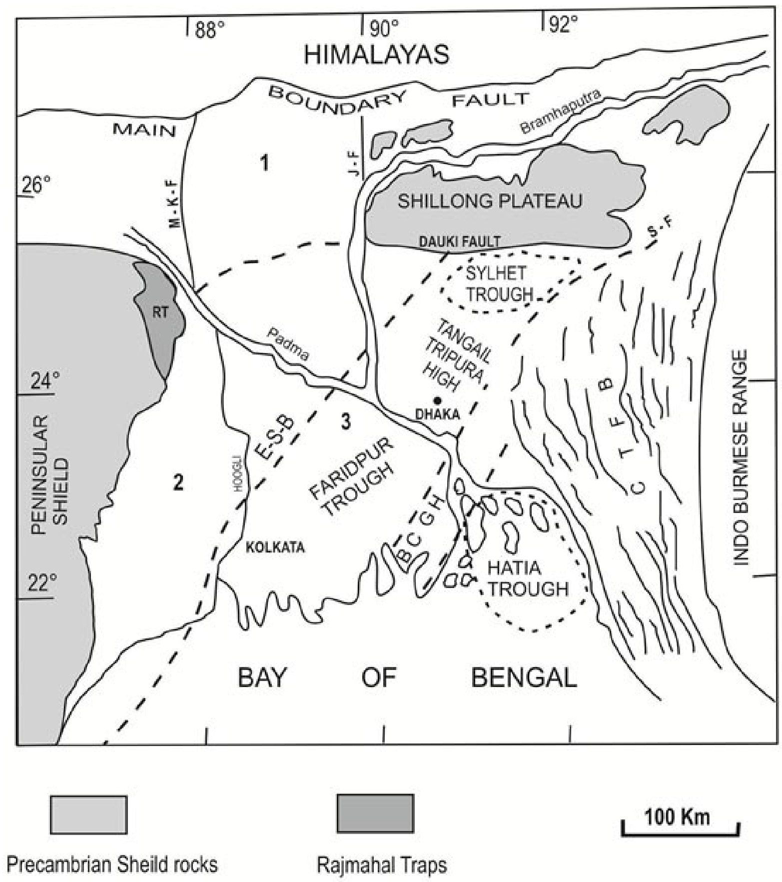

Figure caption : 1, Northern Sub-basin; 2, Western Sub-basin; 3, Southeastern Sub-basin; J–F, Jamuna Fault; M–K–F, Malda–Kishenganj Fault; S–F, Sylhet Fault; E–S–B, Eocene Shelf-break; BCGH, Barisal–Chandpur Gravity High; CTFB, Chitagong–Tripura Fold Belt. Discontinuous lines represent domains of tectonic boundaries (After Roy and Chatterjee, 2015).

delta complex in the world. Although most of the Bengal Basin is slowly subsiding, the troughs are subsiding more rapidly. Both Kolkata and Dhaka are located within the domain of Faridpur Trough (see figure below). The primary cause of subsidence related damages in both the cities is the heterogeneity in the rate of subsidence, which may be because of several local causes mainly the subsurface composition of soil and partly and locally could be due to compaction linked to the conversion of carbonaceous matter to peat. However, we cannot totally forget the role of gravity (low) as the cause of subsidence in the region. Because the 'trough's are invariably alternated by zones of gravity highs.

Further Rearing

A. B. Roy and Alokesh Chatterjee (2015) Tectonic framework and evolutionary history of the Bengal Basin in the Indian subcontinent. CURRENT SCIENCE, Vol. 109, No. 2, 25 July, pp. 271-279.

ROLE OF TRANSITION ELEMENTS IN THE COLOURATION OF PRECIOUS AND SEMI-PRECIOUS MINERALS

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A mineral is a naturally occurring, inorganic, homogeneous solid, having definite chemical composition and fixed internal atomic structure. *Precious* and *semi-precious* minerals or *gem* minerals are those that can be cut and polished, and used in ornamentation. They have the following properties.

1. ***High Degree of Lustre:*** The gem minerals generally have a very high degree of lustre, so they appear much brighter than most other minerals.

2. ***Transparency and High Refractive Index:*** Value of some gem minerals like diamond, corundum etc. depends greatly on their transparency or clarity. If the specimens become opaque due to some crystal defect or impurities, their value decreases.

   The transparent gem minerals have very high refractive indices, e.g. the refractive index of diamond is 2.42. This is responsible for the *sparkling* property of the gem minerals.

3. ***High Hardness:*** A gem mineral must have high hardness, otherwise its polish will wear-off easily.

4. ***High Tenacity:*** Tenacity refers to the resistance of a mineral against breaking. A gem mineral must have high tenacity, otherwise it will not last long.

5. ***Rarity:*** As the supply of a mineral diminishes and it becomes rare, its value increases. If, on the other hand, a mineral becomes abundant through discovery of new sources, its value decreases. Diamond, ruby, sapphire and emerald are very rare in nature, so their cost is very high.

There are more than 3000 mineral species in nature. Only 70 of them are considered as the gem minerals, on the basis of the above attributes. 15 highly valuable gem minerals are selected as precious minerals, and the other 55 are the semi-precious minerals. Some of them are listed in Table 1 (After Klein 2002).

NON-SILICATES

NAME	***CHEMICAL COMPOSITION***	***COLOUR***
Diamond	C	Colourless, usually pale shades of red, orange, brown, light yellow, green, greenish blue, blue
Corundum	Al_2O_3	*Pure Corundum* – Colourless *Ruby* – red *Sapphire* – blue
Spinel	$MgAl_2O_4$	Colourless, translucent to opaque; white, lavender, blue, green, brown, red, black.
Chrysoberyl	$BeAl_2O_3$	*Cat's Eye* – green or yellow.
Malachite	$Cu_2CO_3(OH)_2$	Bright green
Azurite	$Cu_3\,(CO_3)_2\,(OH)_2$	Azure-blue
Rhodochrosite	$MnCO_3$	Rose-red
Turquoise	$CuAl_6(PO_4)_4(OH)_8$	Blue-green

SILICATES

NAME	***COMPOSITION***	***COLOUR***
Olivine(Peridot)	$(Mg,Fe)_2\,SiO_4$	Colourless, pale green to olive green. Colour darkens with increasing amount of Fe^{+2}
Almandine	$Fe_3Al_2(SiO_4)_3$	Red. (known as *red garnet*)
Spessartine	$Mn_3Al_2(SiO_4)_3$	Orange (known as *orange garnet*)
Uvarovite	$Ca_3Cr_2(SiO_4)_3$	Green (known as *green garnet*)
Zircon(Jacinth)	$ZrSiO_4$	Commonly brown. Also colourless, gray, green or red.
Topaz	$Al_2SiO_4(F,OH)_2$	Colourless, yellow, pink, reddish brown, pale blue, pale green.
Beryl	$Be_3Al_2\,(SiO_3)_6$	*Aquamarine* – transparent, greenish blue. *Morganite* – pink to deep rose red. *Emerald* – transparent, deep green. *Golden Beryl* – clear, golden yellow.

TABLE 1. Some Important Precious and Semiprecious Minerals

Geological Institute

NAME	COMPOSITION	COLOUR
Rhodonite	$MnSiO_3$	Pink
Jadeite	$NaAl(SiO_3)_2$	Apple green to emerald green.
Quartz	SiO_2	*Amethyst* – transparent, bright violet.*Citrine* – light yellow.*Cat's Eye* – green or yellow.
Opal	$SiO_2.nH_2O$	Colourless, transparent to translucent. Also, pale shades of yellow, green, gray, pink and blue. May show a fine play of colours.

TABLE 1 (Continued). Some Important Precious and Semiprecious Minerals

Based on colour, the above minerals can be divided into two categories:

1. ***Idiochromatic Minerals:*** these minerals have constant colour – the colour does not vary from specimen to specimen. (Greek *idios* – self or private, *chrome* - colour).Example: azurite is an idiochromatic mineral, and all specimens of azurite are bright blue in colour. Malachite, rhodochrosite, turquoise, almandine, spessartine, uvarovite and rhodonite are the other idiochromatic minerals in Table 1.

2. ***Allochromatic Minerals:*** the colour of these minerals is not fixed – it varies from specimen to specimen. (Greek *allos* – different or variable, *chrome* - colour). Example- some specimens of quartz are colourless, others are bright violet, rose-red, pink or yellow. Most of the minerals in Table 1 (except opal and the seven idiochromatic minerals) are allochromatic.

Now the questions arise –

- Why the idiochromatic minerals have constant colours?
- What causes the variation of colour in allochromatic minerals?

Let us study the chemical compositions of the seven idiochromatic minerals in Table 1. Mn^{+2} is one of the constituent elements of rhodonite, spessartine and rhodochrosite, while malachite, azurite and turquoise have Cu^{+2} ions in them. Almandine contains Fe^{+2}, and Cr^{+3} is present in uvarovite. Fe, Cr, Cu and Mn are transition elements.

There are ten transition elements in the 4^{th} period, B-subgroup of the periodic table – Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu and Zn. They have a strong pigmentation property. These elements have partially filled *d* orbitals. The quantum of energy available in the visible spectrum is sufficient to excite the electrons of the *d* orbitals. These excited electronic states are the basis for colour production.

In the next section, we shall see how the electronic structure of the transition element is related to its pigmentation property.

The Pigmentation Property of Transition Elements

The electrons in atoms and ions occur in discrete orbitals with a precisely defined energy level. The orbitals are separated by finite energy differences. When moving in a definite orbital, an electron neither absorbs nor radiates energy.

Absorption of some electromagnetic wave transfers the electrons from lower to higher energy orbitals, and the energy of incident electromagnetic wave transfers the electrons from higher to lower energy orbitals. The lowest energy state of an atom or ion is known as the ground state. After absorption of energy, they exist in an excited state. The energy difference between the excited state and the ground state is known as the energy gap.

When white light is incident on an atom or ion, it may transfer the electrons to a higher energy orbital if the quantum of energy available in the light is same to the energy gap. In that case, the quantum of energy is absorbed, and the atom or ion goes to an excited state. Then the absorbed energy is re-radiated, and the atom goes back to the ground state.

If the energy of the incident light is greater or less than the energy gaps in an atom, it will pass through the atom without absorption.

There are ten transition elements in the 4^{th} period, B-subgroup of the periodic table – Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu and Zn. These elements have partially filled d orbitals. For example, the electronic configuration of Cr is as follows:

$$1s^2 2s^2 2p^6 3s^2 3p^6 3d^3$$

The quantum of energy available in the visible spectrum is sufficient to excite the electrons of the d orbitals and transfer them to the unoccupied higher orbital. Thus, they absorb the energy and go to the excited electronic states. Due to the high amount of absorption, these elements are opaque or nearly opaque.

Then the electrons come back to the ground state from the excited state, and the absorbed energy is radiated. The absorption and re-radiation of energy are instantaneous, and occur simultaneously in the atoms. In case of the transition elements, the wavelength of the radiated energy is within the range of visible light (i.e. 4000 to 7000 Angstrom). For this reason, each of them has a distinctive colour of its own, and imparts a colour to the crystal in which it occurs.

Colouration of Idiochromatic Minerals

In the idiochromatic minerals, the transition elements are present as the essential constituents and give them their characteristic colour. In a particular mineral species, the elemental constituents are fixed. For this reason, its colour is also fixed and does not vary from specimen to specimen.Examples are as follows.

Mineral Name	***Colour***	***Transition Elements Present***
Chalcopyrite	Golden yellow	Cu, Fe
Pyrite	Brass Yellow	Fe
Malachite	Bright green	Cu
Azurite	Bright blue	Cu
Rhodonite	Pink	Mn
Rhodochrosite	Pink	Mn

TABLE 2. The characteristic colour of some idiochromatic minerals and the transition elements present in them

Colouration of Allochromatic Minerals

The constituent elements of the allochromatic minerals generally do not have any pigmentation property. Therefore, most of them are colourless in pure form. However, trace amounts of one or more transition elements may be present as impurities in the crystal of an allochromatic mineral.

There are two modes of occurrences of impurities in the allochromatic minerals:

- ***Interstitial Solid Solution***: The atoms or ions of transition elements fill up the intermolecular spaces in the mineral.
- ***Ionic Substitution***: The atoms or ions of transition elements replace

some constituent atoms or ions of the mineral, and occupy that place.

Variation of Colour: When present as impurity, each transition element produces a distinct colour in a particular mineral. If different impurities are present in different specimens of a same mineral, they will show different colours. For this reason the colour of an allochromatic mineral varies from specimen to specimen.

Variation of Intensity of Colour: The colouring effect of transition elements is intensified when two different valence state of the same element co-exists in a mineral; e.g. if a mineral contains iron in Fe^{+2} state only, then the mineral is rather pale in colour. But the presence of both Fe^{+3} and Fe^{+2} produces a bright coloration.

The following examples illustrate the role of transition elements in the colouration of allochromatic elements.

- Pure quartz is colourless. Presence of transition elements in trace amounts causes the variations in colour. *Amethyst* contains trace amounts of Fe^{+3}, and *citrine* contains trace amounts of Fe^{+2}.
- Pure corundum is colourless. In ruby, very small amount of Al^{+3} is replaced by Cr^{+3}. This substitution produces the bright red coloration. Sapphires are blue due to trace amounts (a few ppm) of Fe^{+3} or Ti^{+4}.
- Pure beryl is colourless. Substitution of Al^{+3} by Cr^{+3} produces the bright green coloration of emerald. Trace amounts of Fe^{+3} and Fe^{+2} are present in golden beryl and aquamarine respectively. Mn^{+2} produces the coloration of morganite.

CONCLUSION

The preceding discussion may be summarized as follows:

- The transition elements have strong pigmentation property, and they are responsible for the colouration of many precious minerals.
- In the idiochromatic minerals, the transition elements are present as essential constituents. Since the elemental constituents in a particular mineral are fixed, its colour is also fixed.
- In the allochromatic minerals, trace amount of one or more transition elements are present as impurity. As the composition and concentration of the impurities vary, the colour of the allochromatic mineral also varies from specimen to specimen.

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SCALE

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Scale is a very important term in geology. Everything that is described in geology, makes sense only when the scale of it is mentioned. However, at the same time, the fractal nature of some structural elements defies all bounds of the scale. Recently, during my summer internship, I realised the beauty of both these terms.

We all know that the Himalayas were formed due to the subduction of the Indian plate beneath the Eurasian plate. This collisional zone spans all along the southern boundary of the largest continent of the world, Asia, as well as its neighbouring continent, Europe.

The Himalayan mountain range can be divided into four zones, bounded by the principal thrusts of the Himalayan tectonic regime.

These zones, going from south to north, are:

———Himalayan Frontal Thrust——

1. SUB HIMALAYA

————Main Boundary Thrust———

2. LESSER HIMALAYA

————Main Central Thrust————

3. GREAT HIMALAYA

——South Tibet Detachment Fault———

4. TETHYS HIMALAYA

——Indus-Tsangpo Suture Zone———

The Himalayan Frontal Thrust (HFT) separates the Quaternary sedimentary rocks of the Sub Himalaya from the unconsolidated Indo-Gangetic plain sediments. The HFT is the southern leading edge of the Himalayan mountain range and is marked by the riding of the Mohand anticline in the Sub Himalaya over the Indo-Gangetic plain sediments in the Kumaun region. All the three thrusts, namely, Himalayan Frontal Thrust, Main Boundary Thrust and Main Central Thrust, are north dipping thrusts. The South Tibet Detachment Fault is a North dipping normal fault.

These five faults are given special importance because they are almost continuous throughout the 2400km length of the Himalayas.

My study area was at the Main Boundary Thrust near Rajpur, Uttarakhand. Here, the Chandpur phyllites of the Lesser Himalayas are thrust against the Siwalik sandstones of the Sub-Himalayas.

The most amusing part of my study was that, to know which block was thrust upon which one in the region (the two blocks being easily distinguishable by their composition, grade of metamorphism and morphology), all I had to do was study a small part of a 40m long section. (Fig 1)

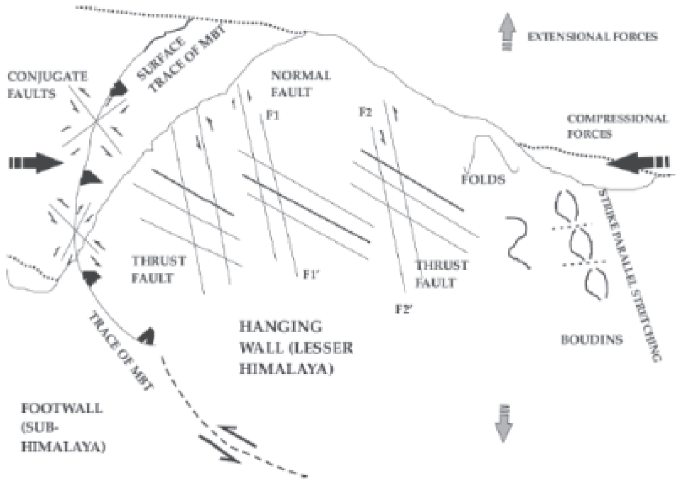

Fig 1: Schematic model fortfie formation of the various tectonic structures at the base of the hanging wall of the MBT

This 40 m long section contained more number of thrust related structures than I could have possibly imagined. Thrust faults could be identified in scales of centimetres. Thrust related conjugate faults could be identifies in scales of centimetres. We know that if a body is put under unidirectional stress, than the first fractures formed are conjugate fractures, at an angle of 30° to σ_1. To perceive that the gigantic stress applied by the huge tectonic plates would not even spare a few centimetres to leave their mark, their signature, and make the conjugate fractures at all scales, is an experience in itself.(Fig 2)

Similarly oriented conjugate faults might be forming huge strike slip faults and normal faults oriented normal to the trend of the Himalayas, in some other areas,

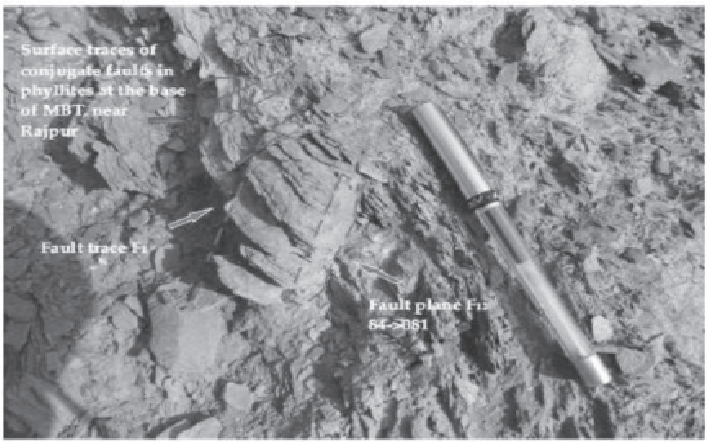

Fig 2 : Conjugates on phyllites at the base of the hanging wall of MBT near railplir. (Section 2 Location 1) while here, they only manifest themselves as little centimetre scale faults, to be seen only if you are actually looking for them.

Needless to mention, there were quite a few folds as well, ranging from 5cm to 5m in scale.

That compression and extension generally occur hand in hand could also be seen in the form of the boudins formed just beside the thrust faults. (Fig 3)

When I first started studying geology, everything I studied, had occurred in such huge spatial and temporal scales, that it was actually difficult to even imagine them at times. Even now, when we go for field work, we, students, generally notice only that which almost shouts aloud its presence to us. Seldom do we take the time to sit down, and look at a section a bit more closely. Not just at an outcrop scale, but look at it in a hand sample scale right there in the field. Every small inch of a rock has its own story to tell. Our petrology classes are supposed to teach us exactly that. But as has been the case with myself, and probably most of my friends too, thinking beyond the mappable units does not come easily to us. However, as it is gradually appearing, nature holds its best stories in the smallest of pockets. Hence, we should not overlook anything just because it is in a small 'scale'. Apparently, geology is a subject,that can take you from the atoms to the secrets of the vast universe, in matters of seconds; where stories spanning over hundreds of millions of years can be compressed within sections spanning less than a metre. It is our duty to take notice of them, and let the mysteries unfold.

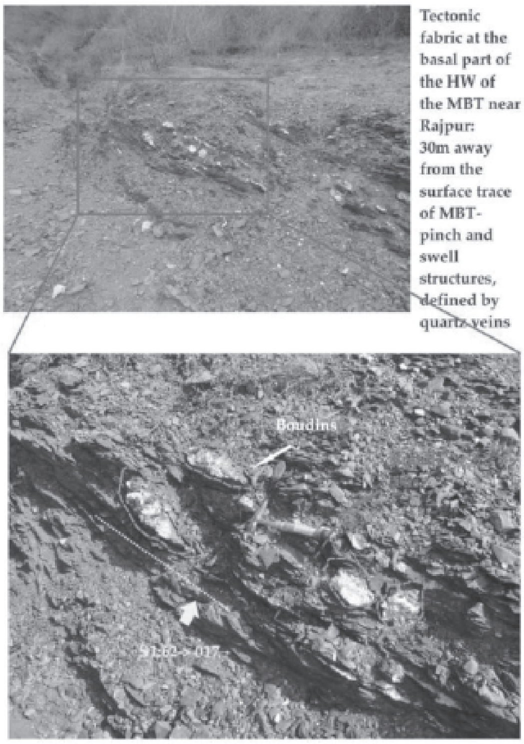

Fig 3: Tectonic fabric at the basal part of the HW of the MBT near Rajpur: 30m away from the surface trace of MBT- pinch and swell structures, defined by quartz veins

Implementation of Stereographic and Spherical Projection in Structural Geology with JavaScript and the web through SvgNet

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Abstract

Projections are a “prescribed” part of structural analysis and visualizations, with the change in day and age numerous computer applications have been written to aid this. Most of them have taken care in explaining and elaborating the mathematical and programmatic aspects of their implementation. These applications and/or programs all have attained a robust and well accepted status in the field. The previously developed programs have mostly taken a traditional approach in code and design, i.e. the use of programming languages like C/C++, Fortran, Java, Python or packages like Matlab, Mathematica etc.

The Open Source Web application discussed here takes up the task of removing system dependencies of the code by the use of JavaScript, the language of the web-browsers, for the entirety of the programming, and improves portability of the output by ***directly*** plotting into Scalable Vector Graphics(SVG).

1. Introduction

Representation of orientation of linear and planar elements in spherical and stereographic projection inevitably aid Structural Geologists with their research and other objectives.

Thus a proper approachable method is to be followed when projections are dealt with, fundamentals of projections have deep seated roots inside mathematics and analytical geometry which are generally not discussed in structural geology textbooks, however literature like Goodman and Shi [1985] and Pollard and Fletcher [2005] respective describe and review the basic concepts, the analytical expressions necessary to plot the attitudes of planar and linear structural elements in the equal-angle and the equal-area lower hemispherical projections, and discuss the construction techniques for those nets, which serve as the backbone of the algorithms used in the discussed application. Majority of available orientation analysis packages(like Cardozo and Allmendinger [2013], Vollmer [2015]) are developed on system dependent native programming languages or scripting packages and produce raster output which may be exported into the vector format. ***SvgNet.js*** removes this hurdle by generating *SVG(Scalable Vector Graphics)* markup directly from input data as inline SVG in an HTML Document Object, via a JavaScript code, more commonly referred to as Document Object Model (DOM) which is a cross-platform and language-independent convention for representing and interacting with objects in HTML, XHTML, and XML documents. In simple terms its a JavaScript application program interface(API) which generates a vector description (in line SVG elements) representing the graphic output, from the data i.e. linear or planar attitudes within a simple web-browser interface.

2. Expressions and Relations

Leaving aside the rigorous analytical and geometrical procedures discussed in Goodman and Shi [1985] and Pollard and Fletcher [2005] the expression that are necessary, and have been used, for the programmatic implementation of the graphical projections are discussed below. The reference Cartesian or polar coordinate system used in all of the following equations have their center coinciding with the center of the reference sphere and primitive circle.

2.1 Equal-Angle Lower Hemispherical Projection

2.1.1 Planar Attitudes

The stereographic projection of the inclined plane is a circle whose center is at C, and whose radius, r, are accordingly determined by, From [Goodman and Shi, 1985, p. 67-68]

$$r = \frac{R}{\cos\alpha} \qquad (1)$$

and the coordinates of the center of the circle representing the plane

$$(Cx, Cy) = (R\tan\alpha\sin\beta,\ R\tan\alpha\cos\beta) \qquad \text{.....}\ (2)$$

where R is the radius of the primitive circle, α and β are the dip and dip direction, respective, of the planar element.

It is to be noted that the scope of projection is for one hemisphere only hence the projection of a planar elements on the Wulff net is an arc which starts at the point (R, θ) and ends at $(R, \theta + \pi)$, where θ is the strike of the plane i.e. according to the Right Hand Rule $(\beta = \pi/2)$.

2.1.2 Linear Attitudes

These are the equations used to plot the projection of a linear element on a stereonet of radius R, given the azimuth of plunge, α, and angle of plunge, ϕ, from [Pollard and Fletcher, 2005, p. 59]

$$(x, y) = \left[R\tan\left(45° - \frac{1}{2}\phi\right)\sin\alpha,\ R\tan\left(45° - \frac{1}{2}\phi\right)\cos\alpha\right] \qquad \text{....}\ (3)$$

this equation 3 is generally used for plotting linear and planar elements,as a family of linear elements, but

SvgNet.js does't use this for equal-angle projection of planes, for the sake of simplicity, reduced number of steps in plotting a great circle directly as a circle due to the availability of a vector elliptical arc implementation in the SVG path element.

2.1.3 Small Circles

The locus of lines (through a common origin) making an equal angle with a given direction through the origin is a cone. This cone pierces a sphere about the origin along a circle; it is denoted a small circle because it can be generated also by the intersection of the reference sphere with a plane that does not contain the origin. By the fundamental property of stereographic projection[Goodman and Shi, 1985, p. 93-94], any small circle on the reference sphere in the projection plane[Goodman and Shi, 1985, p. 71]. A bit geo-logically a pair small circles in a stereonet reference grid can be imagined as the locus of projection of all line which have the same *rake* on a plane with a fixed *strike* and varying i.*dip* and ii. *dip direction*, which can be expressed as function of semi-epcial angle ω and the R, the radius of the primitive circle as a circle with radius,*s* and center (*Sx, Sy*),

[Goodman and Shi, 1985, p. 75]

$$s = R\tan\omega \tag{4}$$

$$\left(S_x, S_y\right) = \left(0, \frac{\pm R}{\cos\omega}\right) \tag{5}$$

2.2 Equal-Area Lower Hemispherical Projection

This projection system is weakly developed presently in the application as the statistical implications are not yet worked out with in the API, yet this projection is done in a fairly cumbersome manner by the use of a single expression that relates the *xy* coordinates of the projection to the trend and plunge of a linear attitude. Hence, planar elements are projected as the a line through a fixed number of points on the beizer cubic curve i.e. the projection of planes in this system. Although SVG supports the drawing of these curves though the four control points a proper computational approach of plotting them as the ideal cubic curve is not well written about in any literature. Mostly due to the fact that this projection is used for statistical analysis where it is generally more convenient,owing to a generic good sample size, to plot the poles to a plane than the plane itself .

The coordinates of a point on the Schmidt net of radius R representing the orienta- tion of a linear element with plunge direction, α , and plunge angle, ϕ (foliations or other planar fabrics the azimuth and plunge of the normal) are , from [Pollard and Fletcher, 2005, p. 66]

$$(x, y) = \left[R\sqrt{2}\sin\left(45° - \frac{1}{2}\phi\right)\sin\alpha,\; R\sqrt{2}\sin\left(45° - \frac{1}{2}\phi\right)\cos\alpha\right] \tag{6}$$

3. JavaScript,SVG and the DOM

3.1 SVGs

Since SVG is the graphical component of the discussed application, here is a brief description of the tools the vector graphic language provides, that have been integrally used in the program.

According to Dailey [2010] ***Scalable Vector Graphics (SVG)*** is a Web graphics language. SVG defines markup and APIs for creating static or dynamic images, capable of interactivity and animation, including various graphical effects. It can be styled with CSS, and combined with HTML.

The default coordinate system in SVG is much the same as in HTML. It works as a two-dimensional x - y plane. The origin (where x = 0 and y = 0) is the upper left-hand corner. As we move right from there, x increases. As we move downward, y increases.

3.1.1 SVG Elements

The <line> object draws a line between two specified points: (*x*1, *y*1) and (*x*2, *y*2). In

order to see the line, it must have a stroke (i.e., a color). Hence, a sort of minimal line consists of code such as the following:

<line x1 = "5" y1 = "5" stroke = "red" x2 = "90" y2 = "90" />

The <circle> does have a slightly simpler syntax the simplest circle requires only a center point (*cx, cy*) and a radius,*r*:

<circle cx="80" cy="50" r="40"/>

<path> is a very flexible drawing option. It renders the movement of a stylus through two dimensions, with both pen-up and pen-down options, including straight and curved segments joined together at vertices which are either smooth or sharp. One other aspect of the <path> deserves mention. That is the ***elliptical arc***. It might seem that an arc would be a very simple topic, but that given any two points in the plane and two elliptical radii, there often are two ellipses that traverse those points with specified radii and those points specify two different arcs for each ellipse. The arc subcommand of the <path> has the following syntax: A rx ry XAR large-arc-flag sweep-flag x y. The arc begins at the current point (determined by the last coordinate specified, e.g. by the M subcommand), and ends at (*x, y*). The ellipse will have radii of rx and ry, with the x-axis of the ellipse being rotated by XAR degrees. The particular ellipse (of the two possible) is specified by the large-arc-flag (0 or 1) and the particular segment of the ellipse is specified by the sweep-flag. (0 or 1).

It begins by specifying where the drawing will begin by inserting as the first element of *d* a notation such asx y for numbers x and y. It might be though of as M x y as meaning *move pen to* *the coordinate x y*. From there the options of moving (with pen still down on the canvas)

- linearly (L),
- quadratically (Q),
- cubically (C)
- or through an elliptic arc (A).

For example, d=”M 100 100 L 200 200" would succeed in drawing a diagonal line from

the point (100, 100) to the point (200, 200) as shown.

<path stroke=”black” d=”M 100 100 L 200 200"/>

3.2 SvgNet.js

The javascript file which is the core of all the functionalities of this application is named SvgNet.js, accessible via the open-source repository at https://github.com/arijitlaik/SvgNet/, not only provides API level functions which can be used to generate plots from input data like strike, dip, pitch plunge, rakes etc but also provides some basic SVG plotting API function, all of these could be used in a browser JavaScript console. Thus successfully providing for all the functionalities like

1. minimal, non dependent API methods to create svgs

2. functions to create svg elements from input data of attitudes

3. Objects oriented approach and access e.g. the plane, with their inherent properties like strike,dip and other properties like colour and thickness of its plot, which is another object with its intrinsic properties)

Unlike many other programming languages, JavaScript does not define different types of numbers, like integers, short, long, floating-point etc. JavaScript numbers are always stored as double precision floating point numbers, following the international IEEE 754 standard. This format stores numbers in 64 bits, where the number (the fraction) is stored in bits 0 to 51, the exponent in bits 52 to 62, and the sign in bit 63. Consequently these are passed on to the SVG attribute values, giving a more precise plot representation, although this precision does add a size constrains of polyline elements with lots of data points.

3.3 Usage

The SvgNet.js is intended to be a standalone wrapper for structural geology projection plots, and could find usage a an plotting API or an application after binding it with an standardised user interface and utility provisions. By virtue of its base in web based standards its inter-portability and device independent nature could aid both field based and later stages of structural analysis or as a library for the real-time cross-client display of orientation data.

3.3.1 Description of function objects and prototypes

Following is a brief discussion of the function objects, object prototypes and variables used in the API

SchmidtNet_Flag: the global *boolean* variable to determine projection type

Pt(x_cord, y_cord) : object prototype for a set of Cartesian coordinates with members x and y, as specified by the argument

center: the global variable of type *Pt* representing the center of the figure in the svg coordinate system

radius_primitive: global variable storing the radius of the primitive circle

Svg_obj(in_id, id): is the object constructor for a new SVG object, i.e. creates a SVG within the *in_id* element with the argument specified *id*

cart2svg(cart_cords) : returns the SVG coordinate transformation of Cartesian coordinate arguments

torad(degrees) : returns the radian approximation of *degrees*.

todeg(radians) : returns the degree approximation of *radians*.

linText(start,end) : returns the *d* attribute for a straight line from the point (*start.x, start.y*) to the point (*end.x, end.y*) , calls the cart2svg for coordinate transformation

polytext(points) : returns the *d* attribute for a polyline through the points in (*points*[*i*].*x, points*[*i*].*y*) where *i* = 0, 1, 2, 3 . . . *points.length*

arcText(start_angle, radius, end_angle, ccw) : returns the *d* attribute for a circular arc with radius and between the polar coordinates (*r, start_angle*) and (*r, end_angle*) the argument ccw is boolean indicating the sense of movement between the specified points

Path_obj(d, stroke, stroke_wth, fill, deg, id): Object prototype of a SVG path element which creates a <path>, with the given arguments as its attributes, the *d* being generated by or a direct call to the d attribute generator functions such as arcText(), polyText, lineText, as child of a Svg_obj, intended to be used with plotting non-point projected elements like lines, poles to planes etc

Circ_obj(cen, radius, stroke, stroke_wth, fill, deg, id) Object prototype of a SVG circle element which creates a <circle>, with the given arguments as its attributes, as child of a Svg_obj

Wtp2cart(plunge, trend) : applies the equation 3 to convert the trend and plunge to cartesian coordinates returning it object of type Pt

Stp2cart(plunge, trend) : applies the equation 6 to convert the trend and plunge to cartesian coordinates returning it object of type Pt

Ssdr2cart(strike, dip, rake, op_flag) : this utilizes a trigonometric conversion from rake data to trend and plunge with the help the equations

trend = *strike* + tan-1(*cos*(*dip*))(tan(*rake*)) (7)

Plunge = sin-1 (sin(*dip*))(sin(*pitch*)) (8) this function also take into consideration the strike end from which the rake, conventionally maximum 90, is measured w.r.t. the RHR strike put in as the argument, and does necessary augmentations

Plane(strike, dip, clr, lwidth, id): Apart from the necessary properties like strike, dip, colour, stroke width, and id, this prototype has a member function draw() which creates the property plot an object of type Path_obj depending on the dip and projection type. The plot is a arc of radius defined in equation 1 in a *Wulff net* and a poly-line estimation of points that are projections of lines which have rake of 0 to 90 measured from both the strike ends of the Plane, in a *Schmidt net* and a line when *dip* = 90. This draw() functions call Ssdr2cart() for the conversion of rake type data to Cartesian coordinate data used in the poly line estimation. The modify function of this object allows modification of a previously created *Plane* object after its strike/dip are changes. Object prototypes for attitudes that plot as point objects are

1. ***Line(trend, plunge, clr, id)*** : the simple line object constructor

2. LineonPlane(onPlane, pitch, op_flag, clr, id) : the line on a plane, i.e parameter onPlane is an object of type Plane but has not plot object, as Plane.draw() is called only when the colour: clr is passed on to as argument of parameter, passes the values obtained from equn. 8 and equn. 7 and the op_flag to Stp2cart and Wtp2cart.

3. ***PoletoPlane(ofPlane, clr, id)***: the pole to plane which similarly uses a no-plot

Plane object as a parameter to calculate the trend and plunge of the pole.

These prototypes hold design similarity to Plane in context of the the member functions draw(): which creates Circ_obj with radius 2 or 1 pixels, with centres determined by equations 6 or 3; and modify() function.

The object prototypes ***WulffNet()*** and ***SchmidtNet()*** are the for the creation of nets of the respective types, with grid intervals of 5s .

Wulff Net great circles and small circles are Path_obj function calls with the "d" parameter arguments being returned by arcText function with radii according to equations 1 and 4 respectively.

Schmidt Net being draw by loci line estimations of cubic curves, estimated from the rake on a plane to trend/

plunge data then to Cartesian Coordinates by the use of the iSsdr2cart which then uses ii. Stp2cart, finally all the data points 5 intervals of rakes for planner projections,5 intervals of dip and a single dip direction change for conical surface(equivalent to small circles) are passed as an array of Pt type objects to the polytext function which returns the *d* attribute to the Path_obj.

4 Conclusion and Roadmap

4.1 Using the SvgNet.js in the SvgNet app

The context of this article has mainly dealt in the procedural part of the application i.e. the design of the API that aids in the building the app, thus User Interface part need little discussion. The API has been designed in such away that it paves the an easy path for HTML5 single page application development work-flow. The function provided can be blinded to HTML elements with much easy and without the use of any external libraries, although input parser and export to raster formats need not be done from bare-bones. The SvgNet.js script combined with other input parser would allow the implementation of data import from cvs and spreadsheets. A minimal Sample Application build on the SvgNet.js is called SvgNet and can be accessed online at https://arijitlaik.github.io/SvgNet it provides data input and the option of saving the thus generated inline SVG for use with any generic Vector Graphics editor like Corel Draw, Inkscape and Adobe Illustrator.

4.2 The Road Ahead

The API is a standalone lightweight library that can be used to render simple Structural geology projections on the Web. The web platform being the to-go place for all the technological diaspora, and the Fluid, Open and System Independent Platform leaves us with a lots of new ways of exploring data, and hence the urge to port exiting native applications to the web is but a necessity. This application being the first of its(Free and Open Source) kind in this field, is still at conceptual Alpha level release. Advanced analytical procedures such as Density Contouring, statistical implications, exporting of the data via JSON (JavaScript Object Notation), a lightweight data-interchange format, for humans to read and write and for machines to parse and generate, needs to be groomed out from the present state. The Developer of the application would be humbly grateful for the reviews(at laikarijit@gmail.com) and advice on taking this code to framework level altitudes which would imply to be a completely robust and portable web infrastructural interface for Structural Analysis on an open and accessible platform.

Important links

Source-code: https://github.com/arijitlaik/SvgNet

Bugs/Issues: https://github.com/arijitlaik/SvgNet/issues

Sample WebApp: http://arijitlaik.github.io/SvgNet/

and its compiled Mobile App: https://build.phonegap.com/apps/1624590/share

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The Point of No Return

Climate Change Nightmares Are Already Here

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Former California Governor and Hollywood superstar Arnold Schwarzenegger had recently stated that climate change and global warming are no longer terms associated with science fiction. They have become a part of today's reality. The worst predicted impacts of climate change are starting to happen — and much faster than climate scientists expected.

Historians may look to 2015 as the year when concern really started hitting the fan. Some snapshots: In just the past few months, record-setting heat waves in Pakistan and India each killed more than 1,000 people. In Washington State's Olympic National Park, the rainforest caught fire for the first time in living memory. London reached 98 degrees Fahrenheit during the hottest July day ever recorded in the U.K.; The Guardian briefly had to pause its live blog of the heat wave because its computer servers overheated. In California, suffering from its worst drought in a millennium, a 50-acre brush fire swelled seventyfold in a matter of hours, jumping across the I-15 freeway during rush-hour traffic. Then, a few days later, the region was pounded by intense, virtually unheard-of summer rains. Puerto Rico is under its strictest water rationing in history as a monster El Niño forms in the tropical Pacific Ocean, shifting weather patterns worldwide.

On July 20th, James Hansen, the former NASA climatologist who brought climate change to the public's attention in the summer of 1988, issued a bombshell: He and a team of climate scientists had identified a newly important feedback mechanism off the coast of Antarctica that suggests mean sea levels could rise 10 times faster than previously predicted: 10 feet by 2065. The authors included this chilling warning: If emissions aren't cut, "We conclude that multi-meter sea-level rise would become practically unavoidable. Social disruption and economic consequences of such large sea-level rise could be devastating. It is not difficult to imagine that conflicts arising from forced migrations and economic collapse might make the planet ungovernable, threatening the fabric of civilization."

Eric Rignot, a climate scientist at NASA and the University of California-Irvine and a co-author on Hansen's study, said their new research doesn't necessarily change the worst-case scenario on sea-level rise, it just makes it much more pressing to think about and discuss, especially among world leaders. In particular, says Rignot, the new research shows a two-degree Celsius rise in global temperature — the previously agreed upon "safe" level of climate change — "would be a catastrophe for sea-level rise."

Hansen's new study also shows how complicated and unpredictable climate change can be. Even as global ocean temperatures rise to their highest levels in recorded history, some parts of the ocean, near where ice is melting exceptionally fast, are actually cooling, slowing ocean circulation currents and sending weather patterns into a frenzy. Sure enough, a persistently cold patch of ocean is starting to show up just south of Greenland, exactly where previous experimental predictions of a sudden surge of freshwater from melting ice expected it to be. Michael Mann, another prominent climate scientist, recently said of the unexpectedly sudden Atlantic slowdown, "This is yet another example of where observations suggest that climate model predictions may be too conservative when it comes to the pace at which certain aspects of climate change are proceeding."

Since storm systems and jet streams in the United States and Europe partially draw their energy from the difference in ocean temperatures, the implication of one patch of ocean cooling while the rest of the ocean warms is profound. Storms will get stronger, and sea-level rise will accelerate. Scientists like Hansen only expect extreme weather to get worse in the years to come, though Mann said it was still "unclear" whether recent severe winters on the East Coast are connected to the phenomenon.

And yet, these aren't even the most disturbing changes happening to the Earth's biosphere that climate scientists are discovering this year. For that, you have to look not at the rising sea levels but to what is actually happening within the oceans themselves.

Water temperatures this year in the North Pacific have never been this high for this long over such a large area — and it is already having a profound effect on marine life.

Eighty-year-old Roger Thomas runs whale-watching trips out of San Francisco. On an excursion earlier this year, Thomas spotted 25 humpbacks and three blue whales. During a survey on July 4th, federal officials spotted 115 whales in a single hour near the Farallon Islands — enough to issue a boating warning. Humpbacks are occasionally seen offshore in California, but rarely so close to the coast or in such numbers. Why are they coming so close to shore?

Exceptionally warm water has concentrated the krill and anchovies they feed on into a narrow band of relatively cool coastal water. The whales are having a heyday. “It’s unbelievable,” Thomas told a local paper. “Whales are all over the place.”

Last fall, in northern Alaska, in the same part of the Arctic where Shell is planning to drill for oil, federal scientists discovered 35,000 walruses congregating on a single beach. It was the largest-ever documented “haul out” of walruses, and a sign that sea ice, their favoured habitat, is becoming harder and harder to find.

Marine life is moving north, adapting in real time to the warming ocean. Great white sharks have been sighted breeding near Monterey Bay, California, the farthest north that’s ever been known to occur. A blue marlin was caught last summer near Catalina Island — 1,000 miles north of its typical range. Across California, there have been sightings of non-native animals moving north, such as Mexican red crabs.

No species may be as uniquely endangered as the one most associated with the Pacific Northwest, the salmon. Every two weeks, Bill Peterson, an oceanographer and senior scientist at the National Oceanic and Atmospheric Administration’s Northwest Fisheries Science Centre in Oregon, takes to the sea to collect data he uses to forecast the return of salmon. What he’s been seeing this year is deeply troubling.

Salmon are crucial to their coastal ecosystem like perhaps few other species on the planet. A significant portion of the nitrogen in West Coast forests has been traced back to salmon, which can travel hundreds of miles upstream to lay their eggs. The largest trees on Earth simply wouldn’t exist without salmon.

But their situation is precarious. This year, officials in California are bringing salmon downstream in convoys of trucks, because river levels are too low and the temperatures too warm for them to have a reasonable chance of surviving. One species, the winter-run Chinook salmon, is at a particularly increased risk of decline in the next few years, should the warm water persist offshore.

“You talk to fishermen, and they all say: ‘We’ve never seen anything like this before,” says Peterson. “So when you have no experience with something like this, it gets like, ‘What the hell’s going on?’ “

Atmospheric scientists increasingly believe that the exceptionally warm waters over the past months are the early indications of a phase shift in the Pacific Decadal Oscillation, a cyclical warming of the North Pacific that happens a few times each century. Positive phases of the PDO have been known to last for 15 to 20 years, during which global warming can increase at double the rate as during negative phases of the PDO. It also makes big El Ninos, like this year's, more likely. The nature of PDO phase shifts is unpredictable — climate scientists simply haven't yet figured out precisely what's behind them and why they happen when they do. It's not a permanent change — the ocean's temperature will likely drop from these record highs, at least temporarily, sometime over the next few years — but the impact on marine species will be lasting, and scientists have pointed to the PDO as a global-warming preview.

"The climate [change] models predict this gentle, slow increase in temperature," says Peterson, "but the main problem we've had for the last few years is the variability is so high. As scientists, we can't keep up with it, and neither can the animals." Peterson likens it to a boxer getting pummelled round after round: "At some point, you knock them down, and the fight is over."

Attendant with this weird wildlife behaviour is a stunning drop in the number of plankton — the basis of the ocean's food chain. In July, another major study concluded that acidifying oceans are likely to have a "quite traumatic" impact on plankton diversity, with some species dying out while others flourish. As the oceans absorb carbon dioxide from the atmosphere, it's converted into carbonic acid — and the pH of seawater declines. According to lead author Stephanie Dutkiewicz of MIT, that trend means "the whole food chain is going to be different."

The Hansen study may have gotten more attention, but the Dutkiewicz

Pavement-melting heat waves in India. Harish Tyagi/EPA/Corbis

study, and others like it, could have even more dire implications for our future. The rapid changes Dutkiewicz and her colleagues are observing have shocked some of their fellow scientists into thinking that yes, actually, we're heading toward the worst-case scenario. Unlike a prediction of massive sea-level rise just decades away, the warming and acidifying oceans represent a problem that seems to have kick-started a mass extinction on the same time scale.

Jacquelyn Gill is a paleoecologist at the University of Maine. She knows a lot about extinction, and her work is more relevant than ever. Essentially, she's trying to save the species that are alive right now by learning more about what killed off the ones that aren't. The ancient data she studies shows "really compelling evidence that there can be events of abrupt climate change that can happen well within human life spans. We're talking less than a decade."

For the past year or two, a persistent change in winds over the North Pacific has given rise to what meteorologists and oceanographers are calling "the blob" — a highly anomalous patch of warm water between Hawaii, Alaska and Baja California that's thrown the marine ecosystem into a tailspin. Amid warmer temperatures, plankton numbers have plummeted, and the myriad species that depend on them have migrated or seen their own numbers dwindle.

Significant northward surges of warm water have happened before, even frequently. El Niño, for example, does this on a predictable basis. But what's happening this year appears to be something new. Some climate scientists think that the wind shift is linked to the rapid decline in Arctic sea ice over the past few years, which separate research has shown makes weather patterns more likely to get stuck.

A similar shift in the behaviour of the jet stream has also contributed to the California drought and severe polar vortex winters in the Northeast over the past two years. An amplified jet-stream pattern has produced an unusual doldrums off the West Coast that's persisted for most of the past 18 months. Daniel Swain, a Stanford University meteorologist, has called it the "Ridiculously Resilient Ridge" — weather patterns just aren't supposed to last this long.

What's increasingly uncontroversial among scientists is that in many ecosystems, the impacts of the current off-the-charts temperatures in the North Pacific will linger for years, or longer. The largest ocean on Earth, the Pacific is exhibiting cyclic variability to greater extremes than other ocean basins. While the North Pacific is currently the most dramatic area of change in the world's oceans, it's not alone: Globally, 2014 was a record-setting year for ocean temperatures, and 2015 is on pace to beat it soundly, boosted by the El Niño in the Pacific. Six percent of the world's reefs could disappear before the end of the decade, perhaps permanently, thanks to warming waters.

Since warmer oceans expand in volume, it's also leading to a surge in sea-level rise. One recent study showed a slowdown in Atlantic Ocean currents, perhaps linked to glacial melt from Greenland that caused a four-inch rise in sea levels along the Northeast coast in just two years, from 2009 to 2010. To be sure, it seems like this sudden and unpredicted surge was only temporary, but scientists who studied the surge estimated it to be a 1-in-850-year event, and it's been blamed on accelerated beach erosion "almost as significant as some hurricane events."

Possibly worse than rising ocean temperatures is the acidification of the waters. Acidification has a direct effect on molluscs and other marine animals with hard outer bodies: A striking study last year showed that, along the West Coast, the shells of tiny snails are already dissolving, with as-yet-unknown consequences on the ecosystem. One of the study's authors, Nina Bednaršek, told Science

Biblical floods in Turkey. Ali Atmaca/Anadolu Agency/Getty

magazine that the snails' shells, pitted by the acidifying ocean, resembled "cauliflower" or "sandpaper." A similarly striking study by more than a dozen of the world's top ocean scientists this July said that the current pace of increasing carbon emissions would force an "effectively irreversible" change on ocean ecosystems during this century. In as little as a decade, the study suggested, that chemical changes will rise significantly above background levels in nearly half of the world's oceans.

"I used to think it was kind of hard to make things in the ocean go extinct," James Barry of the Monterey Bay Aquarium Research Institute in California told the Seattle Times in 2013. "But this change we're seeing is happening so fast it's almost instantaneous."

Thanks to the pressure we're putting on the planet's ecosystem — warming, acidification and good old-fashioned pollution — the oceans are set up for several decades of rapid change. Here's what could happen next.

The combination of excessive nutrients from agricultural runoff, abnormal wind patterns and the warming oceans is already creating seasonal dead zones in coastal regions when algae blooms suck up most of the available oxygen. The appearance of low-oxygen regions has doubled in frequency every 10 years since 1960 and should continue to grow over the coming decades at an even greater rate.

So far, dead zones have remained mostly close to the coasts, but in the 21st century, deep-ocean dead zones could become common. These low-oxygen regions could gradually expand in size — potentially thousands of miles across — which would force fish, whales, pretty much everything upward. If this were to occur, large sections of the temperate deep oceans would suffer should the oxygen-free layer grow so pronounced that it stratifies, pushing surface ocean warming into overdrive and hindering upwelling of cooler, nutrient-rich deeper water.

Enhanced evaporation from the warmer oceans will create heavier downpours, perhaps destabilizing the root systems of forests, and accelerated runoff will pour more excess nutrients into coastal areas, further enhancing dead zones. In the past year, downpours have broken records in Long Island, Phoenix, Detroit, Baltimore, Houston and Pensacola, Florida.

Evidence for the above scenario comes in large part from our best understanding of what happened 250 million years ago, during the "Great Dying," when more than 90 percent of all oceanic species perished after a pulse of carbon dioxide and methane from land-based sources began a period of profound climate change. The conditions that triggered "Great Dying" took hundreds of thousands of years to develop. But humans have been emitting carbon dioxide at a much quicker rate, so the current mass extinction only took 100 years or so to kick-start.

With all these stressors working against it, a hypoxic feedback loop could wind up destroying some of the oceans' most species-rich ecosystems within our lifetime. A recent study by Sarah Moffitt of the University of California-Davis said it could take the ocean thousands of years to recover. "Looking forward for my kid, people in the future are not going to have the same ocean that I have today," Moffitt said.

As you might expect, having tickets to the front row of a global environmental catastrophe is taking an increasingly emotional toll on scientists, and in some cases pushing them toward advocacy. Of the two dozen or so scientists I interviewed for this piece, virtually all drifted into apocalyptic language at some point.

For Simone Alin, an oceanographer focusing on ocean acidification at NOAA's Pacific Marine Environmental Laboratory in Seattle, the changes she's seeing hit close to home. The Puget Sound is a natural laboratory for the coming decades of rapid change because its waters are naturally more acidified than most of the world's marine ecosystems.

The local oyster industry here is already seeing serious impacts from acidifying waters and is going to great lengths to avoid a total collapse. Alin calls oysters, which are non-native, the canary in the coal mine for the Puget Sound: "A canary is also not native to a coal mine, but that doesn't mean it's not a good indicator of change."

Though she works on fundamental oceanic changes every day, the Dutkiewicz study on the impending large-scale changes to plankton caught her off-guard: "This was alarming to me because if the basis of the food web changes, then everything could change, right?"

Alin's frank discussion of the looming oceanic apocalypse is perhaps a product of studying unfathomable change every day. But four years ago, the birth of her twins "heightened the whole issue," she says. "I was worried enough about these problems before having kids that I maybe wondered whether it was a good idea. Now, it just makes me feel crushed."

Katharine Hayhoe, a climate scientist and evangelical Christian, moved from Canada to Texas with her husband, a pastor, precisely because of its vulnerability to climate change. There, she engages with the evangelical community on science — almost as a missionary would. But she's already planning her exit strategy: "If we continue on our current pathway, Canada will be home for us long term. But the majority of people don't have an exit strategy. . . . So that's who I'm here trying to help."

James Hansen, the dean of climate scientists, retired from NASA in 2013 to become a climate activist. But for all the gloom of the report he just put his name to, Hansen is actually somewhat hopeful. That's because he knows that climate change has a straightforward solution: End fossil-fuel use as quickly as possible. If tomorrow, the leaders of the United States and China would agree to a sufficiently strong, coordinated carbon tax that's also applied to imports, the rest of the world would have no choice but to sign up. This idea has already been pitched to Congress several times, with tepid bipartisan support. Even though a carbon tax is probably a long shot, for Hansen, even the slim possibility that bold action like this might happen is enough for him to devote the rest of his life to working to achieve it. On a conference call with reporters in July, Hansen said a potential joint U.S.-China carbon tax is more important than whatever happens at the United Nations climate talks in Paris.

One group Hansen is helping is Our Children's Trust, a legal advocacy organization that's filed a number of novel challenges on behalf of minors under the idea that climate change is a violation of intergenerational equity — children, the group argues, are lawfully entitled to inherit a healthy planet.

A separate challenge to U.S. law is being brought by a former EPA scientist arguing that carbon dioxide isn't just a pollutant (which, under the Clean Air Act, can dissipate on its own), it's also a toxic substance. In general, these substances have exceptionally long life spans in the environment, cause an unreasonable risk, and therefore require remediation. In this case, remediation may involve planting vast numbers of trees or restoring wetlands to bury excess carbon underground.

Even if these novel challenges succeed, it will take years before a bend in the curve is noticeable. But maybe that's enough. When all feels lost, saving a few species will feel like a triumph.

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ভূদ্ভিদবিদ্যা

বিদিশা দে,
স্নাতকোত্তর দ্বিতীয় বর্ষ

ভারতবর্ষে এমন কোন খনি নেই যেখানে প্রাচীন খননের চিহ্ন পাওয়া যায় না। খেতরির তামা বা কোলারের সোনা সব বড় বড় খনিতেই প্রাগৈতিহাসিক যুগ থেকে খনন কাজের চিহ্ন পাওয়া যায়।

যা আমাদের আশ্চর্য করে তা হল, সেই সব প্রাগৈতিহাসিক মানুষেরা তাদের সীমীত ভূতাত্ত্বিক জ্ঞান নিয়ে আর সামান্য ছেনি হাতুড়ির সাহায্যে কি করে এই সব খনিজ ভান্ডারকে খুঁজে বের করত?

হয়তো বা তাদের সহজাত জ্ঞান চিনে নিতে পারত ভূপ্রকৃতির প্রকৃত রূপ আর তার তলায় লুকোনো খনিজ ভান্ডারকে। কখনও হয়তো বা তারা ব্যবহার করত সেই এলাকার প্রাণিজগতের বৈচিত্র বা স্বাভাবিক উদ্ভিদের প্রকারভেদ।

উড়িষ্যায় দামাশাল নদীর তীরে বিস্তীর্ণ শালবন, শালগাছের সঙ্গে এখানে আসান, পিয়াশাল ও কোঙরা গাছও উপস্থিত। এইসব বড় বড় গাছের মাঝের শূন্যস্থান দখল করে আছে কুরচি, খরবনা, বনসান ও আতন্ডির মত বিভিন্ন লতাগাছ। এই বিস্তীর্ণ বনের মধ্যে বেশ কিছু জায়গা একেবারে শাল গাছ মুক্ত, সেই জায়গা দখল করে আছে খর্বাকৃতি আসান গাছ এবং ঘন আতন্ডি লতার ঝাড়। কেন এই ব্যতিক্রম? মাটি পরীক্ষা করে পাওয়া গেল নিকেলের আধিক্য। নিকেল ধাতু শালগাছের পক্ষে বিষবৎ, তাই শালগাছের সংখ্যা হ্রাস পেয়েছে এবং আসান গাছের উপর নিকেল প্রভাব ফেলেছে তাদের উচ্চতা খর্ব করে। কিন্তু আতন্ডি লতার সংখ্যাধিক্যের প্রধান কারণও হল এই নিকেল। পরে ড্রিলিং করে উদ্ধার করা হল নিকেলের এক বিশাল ভান্ডার।

রাজস্থানের শুষ্ক রিক্ত মাটিতে জন্মায় এক ধরনের বুনো লতা। নাম গুল মেহেন্দি লতা (*Impatiene balsania*)। তার নজরকাড়া রক্ত রঙের ফুল সিসা (Pb) ও দস্তার (Zn) সহাবস্থানের পরিচায়ক।

শুধু আমাদের দেশেই নয়। উত্তর আমেরিকার অ্যারিজনায় পাওয়া যায় এক ধরনের গুল্ম, ক্যালিফোর্নিয়া পপি (California popy) নামক এই গাছটি শুষ্ক ভূত্বকের উপর একটি নির্দিষ্ট বিন্যাস ধরে বসানো মনে হয়। পরে দেখা যায় মাটির তলায় তামা যুক্ত খনিজের উপস্থিতির উপর নির্ভর করে এই গাছের আধিক্য। অ্যারিজনার এই অঞ্চলে তাম্র-আকরিক (Cu ore) পাওয়া যায় চ্যুতি অঞ্চল (fault zone) ধরে। অর্থাৎ এই অঞ্চলে শুধু তামার উপস্থিতি নয়, চ্যুতির বিন্যাস (fault patterns) সম্পর্কে ও জানা যেতে পারে এই গাছ থেকে।

এই ভাবে মাটির উপরের উদ্ভিদ দেখে অনেক সময়েই মাটির তলার খনিজের উপস্থিতি, শিলাস্তরের প্রকার (rock type), বিন্যাস (sequence) ও অনেক সময় পাললিক শিলার গাঠনিক (structure) বৈশিষ্ট্য সম্পর্কে জানা যায়।

বিশেষ করে যে সব জায়গায় শিলাস্তর মাটির স্তরের নিচে ঢাকা, সেই সব স্থানে, অনেক খরচ সাপেক্ষ ড্রিলিং বা জিওফিজিকাল সমীক্ষা চালানোর তুলনায় এই পদ্ধতি অনেক সহজ ও কম সময় সাপেক্ষ। এই পদ্ধতির বৈজ্ঞানিক নাম হল *Biogeochemical Prospecting*.

আমরা জানি গাছের বেড়ে ওঠার জন্য জল, বাতাস ও সঠিক পরিমাণে সূর্যের আলো এবং মাটিতে থাকা পুষ্টির প্রয়োজন, তাহলে একই অঞ্চলের মাটিতে শুধু মাটির নিচে থাকা ধাতু বা শিলাস্তরের জন্য উদ্ভিদের প্রকৃতির এত তফাৎ হয় কেন?

মাটির নিচে থাকা শিলাস্তর (bed rock) থেকেই

উদ্ভব হয় মাটির, অতএব এই শিলাস্তরে উপস্থিত বিভিন্ন মৌলের উপরেই নির্ভর করে মাটির মৌলের পরিমাণ। মাটির নিচের ভূ-জল এর সঞ্চার (ground water movement) এর মাধ্যমেও শিলাস্তরের ধাতব মৌল মাটিতে উঠে আসে। এই সব মৌল জলে দ্রবীভূত আয়ন হিসেবে উদ্ভিদ দেহে প্রবেশ করে। এখন, সমস্ত মৌলের ক্ষেত্রে সব উদ্ভিদের সহনশক্তি সমান নয়। কিছু কিছু উদ্ভিদ কিছু নির্দিষ্ট মৌলযুক্ত

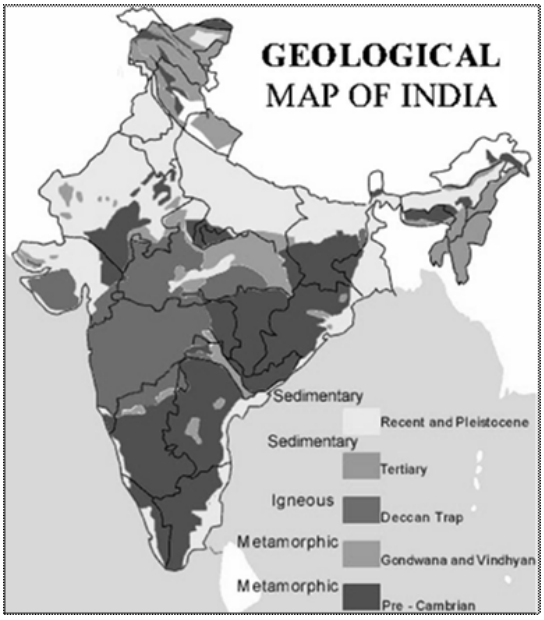

Fig. 1 - ভূ-তাত্ত্বিক মানচিত্র-ভারত

অঞ্চল-এ ভালো জন্মায়, এবং কিছু মৌল আছে যারা কোন স্থানে মাত্রাতিরিক্ত থাকলে সমস্ত উদ্ভিদ জগতের উপর বিষক্রিয়া প্রয়োগ করে। শুধুমাত্র কিছু উদ্ভিদ, যারা এই মৌলকে সহ্য করতে পারে, তাদেরই এইসব স্থানে দেখা যায়।

এইসব উদ্ভিদ, ধাতব মৌলের উচ্চমাত্রায় অভিযোজিত। ধরা যাক, যে কোন এক স্থানে মাটির নিচে অতিরিক্ত পরিমাণে তামা যুক্ত খনিজ আছে। সেই স্থানে মাটির উপর সেখানকার স্বাভাবিক উদ্ভিদ ও আবহাওয়া অনুযায়ী সবরকম উদ্ভিদই জন্মাতে পারে, কিন্তু কিছু উদ্ভিদ, যারা তামার উচ্চ পরিমাণকে সহ্য করতে পারে তারাই এই স্থানে প্রকৃতির দ্বারা নির্বাচিত হয়। ফলে, তারা অধিক পরিমাণে বংশ বৃদ্ধি করে ও যে সব গুণের জন্য তামার এই উচ্চ মাত্রাকে সহ্য করতে পারছে, সেইসব গুণ যুক্ত জিন (gene) গুলি পরবর্তী প্রজন্মে যাবার বেশি সুযোগ পায়। ক্রমে এইসমস্ত গুণগুলি বংশানুক্রমে একত্রিত হয় এবং পরবর্তী প্রজন্মের উদ্ভিদেরা ধাতব মৌলের আধিক্যের

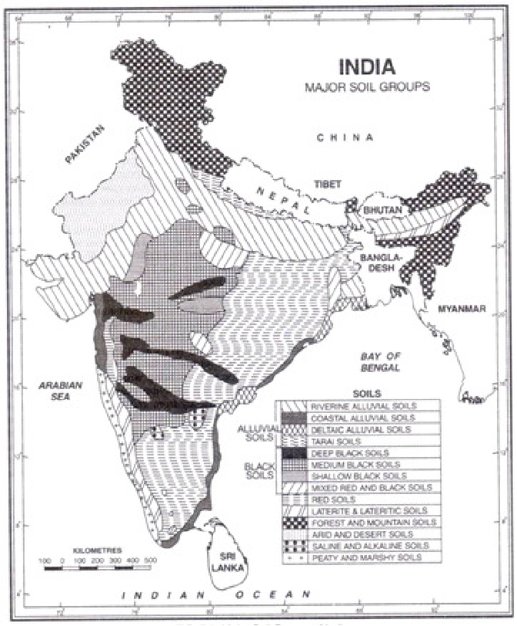

Fig. 2 - মৃত্তিকা মানচিত্র-ভারত

উপর এতটাই নির্ভরশীল হয়ে পড়ে যে মাটিতে ধাতুর পরিমাণ উচ্চ না হলে এদের দেখা যায় না।

মাটির নিচের শিলাস্তরের সাথে মাটির উপরের উদ্ভিদ প্রকৃতির সম্পর্ক খুব সহজে বোঝা যায় ভারতের মানচিত্র লক্ষ করলে।

ভারতের প্রাকৃতিক মানচিত্রের দিকে লক্ষ রাখলে দেখা যায় এক একটি নির্দিষ্ট শিলা প্রকৃতির ওপর এক একটি নির্দিষ্ট প্রকারের কৃষিজ ফসল উপস্থিত । মহারাষ্ট্রের কৃষ্ণ মৃত্তিকার ওপর যে কার্পাস চাষ হয়, তা প্রধানত ব্যাসল্ট জাত (basaltic soil) মাটির

ওপর। একইভাবে, উত্তর ভারতের সমস্ত শস্য জাতীয় উদ্ভিদের (ধান, গম, বার্লি) চাষ হয় গ্র্যানিট জাত মৃত্তিকাতে (granitic soil)।

এর কারণ খুব সহজে ব্যাখ্যা করা যায়, মাটির সৃস্টি হয় তার তলায় উপস্থিত পাথর (bed rock) থেকে। আর মাটির প্রকৃতির ওপরই নির্ভর করে কোন স্থানে কোন ধরনের ফসল এর চাষ ভালো হবে।

ভারতের কৃষি প্রধান অঞ্চলে প্রধানত ৩ ধরনের মাটি পাওয়া যায়। উত্তর ভারতের গঙ্গা-সিন্ধু-ব্রহ্মপুত্র উপত্যকার পলি মৃত্তিকা (alluvial soil), পূর্ব ও দক্ষিণ ভারতের ল্যাটেরাইট ও লোহিত মৃত্তিকা (laterite soil & red soil) যা প্রধানত আর্কিয়ান ক্রেটন ও প্রোটেরজোইক বেসিন (Archean craton & Proterozoic basins) গুলির ওপর অবস্থিত, এবং পশ্চিম ভারতের কৃষ্ণ মৃত্তিকা (black soil) যা ডেকান ব্যাসল্ট (deccan basalt) এর ওপর অবস্থিত।

ভারতের প্রধান খনিজ ফসল গুলির বিস্তৃতি এই তিন অঞ্চল দিয়ে ভাগ করা যায়। প্রায় ৪৬ শতাংশ ধানের ফলন পশ্চিমবঙ্গ, উত্তরপ্রদেশ, পাঞ্জাব ও বিহারে হয়, যা গঙ্গা-সিন্ধু অববাহিকার অর্ন্তভুক্ত। আরো প্রায় ৩০ শতাংশ ধানের চাষ হয় ওড়িশা, তামিলনাড়ু ও অন্ধ্রপ্রদেশের উপকূল অঞ্চল ধরে যেখানে উপকূলীয় পলি মাটি (costal alluvial soil) মহানদী, গোদাবরী ও গঙ্গার মোহনায় দেখা যায়। জোয়ার এর ক্ষেত্রে প্রায় ৭০ শতাংশ ফলন হয় মহারাষ্ট্র ও কর্ণাটকে, এখানকার শিলাস্তর হল ডেকান ব্যাসল্ট ও মাটি কৃষ্ণ মৃত্তিকা। গমের ক্ষেত্রে আবার দেখা যায় ৬২ শতাংশ ফলন হয় উত্তরপ্রদেশ, পাঞ্জাব ও হরিয়ানায়, যা সিন্ধু-গঙ্গা অববাহিকার পশ্চিমাংশ। তুলোর কথা আগেই বলা হয়েছে, সংখ্যাতত্ত্বের হিসেব করলে দেখা যায় ৬৬ শতাংশ ফলন হয় গুজরাত, মহারাষ্ট্র ও অন্ধ্রপ্রদেশ এর কৃষ্ণ মৃত্তিকার ওপর।

মৃত্তিকাবৃত স্থানের ম্যাপিং করার সময় অনেকসময়ই কৃষিজ বা স্বাভাবিক উদ্ভিদ দেখে শিলাস্তরকে চিহ্নিত করা হয়। এর ফলে যেমন ভূতাত্ত্বিক পরীক্ষা করার জন্য যেসময় লাগার কথা তা হ্রাস পায় তেমনই সমীক্ষার জন্য যে বিপুল পরিমাণ অর্থ প্রয়োজন তাও বাঁচানো সম্ভব।

কৃতজ্ঞতা স্বীকার

ভূতত্ত্ববিদ্যার সাথে আমার প্রথম পরিচায়ক বই, সঙ্কর্ষণ রায়ের লেখা 'সন্ধান', যা আমার এই লেখাতেও অনেক সাহায্য করেছে, তার প্রতি কৃতজ্ঞতা জ্ঞাপন করি। আমার সহপাঠী ও শিক্ষকগণ যারা এই লেখাতে আমাকে নানা ভাবে সাহায্য করেছেন, তাদের প্রতিও আমি আন্তরিকভাবে কৃতজ্ঞ। প্রেসিডেন্সি বিশ্ববিদ্যালয়ের ভূতত্ত্ববিদ্যা বিভাগের প্রতি কৃতজ্ঞতা জ্ঞাপন করি আমায় ভূত্ত্বের সাথে এতটা পথ হাঁটার সুযোগ দেওয়ার জন্য।

সহায়কপঞ্জী

১। সঙ্কর্ষণ রায়, সন্ধান

২। Longman school atlas

৩। Utah geological survey website

CONCENTRATION DIAGRAMS

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1. Introduction

Material transport is an important aspect of metamorphism as the loss or addition of any fluid phase during metamorphism can change the bulk composition of a rock rather than simply modifying its H_2O content. Transport of material is necessary for metamorphic reactions to proceed since considerable redistribution of material is required to transform the mineral assemblages of one metamorphic facies to those of another. However, according to the law of conservation of mass and energy, the mass is conserved during such mass transfer mechanisms.

A convenient graphical technique for evaluating mass change is to simply plot altered/precursor concentration ratios on the y axis for the elements of interest arranged in any convenient order on the x-axis-such diagrams are referred to as concentration diagrams.

2. Principles of construction

Firstly, the behavior of the relatively inert elements is carefully studied for determination of the geochemical reference frame. This ratio C/Cp is the inverse of that in the total mass change expression. A value less than one on a CR plot indicates that the concentrations of the low solubility elements were diluted due to the addition of other mobile elements. Conversely, a value greater than one indicates bulk mass loss. The value will be equal to one only for the special case of no bulk mass loss or gain.

Elements added to the rock plot above the reference line whereas elements that were lost, plot below it.

3. Case study

- Here,an attempt has been made to balance mass of a granitic rock which has undergone transformation to amphibole vein.
- After plotting the altered/precursor concentration (C/Cp) ratios for the elements of interest, the following diagram is obtained:
- In the above diagram, it is evident that the concentration ratios for Al, Zr, Na and Hf are all about the same, averaging about 0.767. Thus a line is drawn through 0.767 on the CR graph to establish the reference frame.
- From equation of mass balance, the mass change can be estimated:

$$T_{mass,i} = \left(\frac{C_i^{\,0}}{C_i^{\,'}}\right) - 1 = \left(\frac{1}{0.767} - 1\right) = 0.308$$

[where $C_i^{\,0}$ and $C_i^{\,'}$ = concentration of

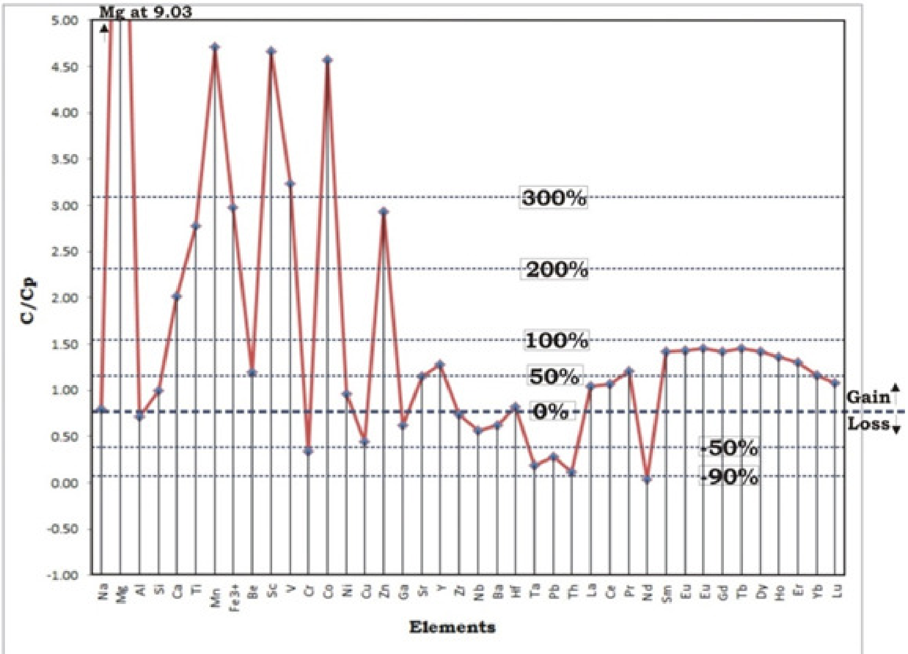

Fig.1: Concentration Diagram for the altered rock relative to precursor rock - Geochemical reference frame is denoted by thick dash line whereas thin dash lines indicate contours of constant mass gain and loss.

reference species i for precursor and altered rock respectively]

Percentage mass change = $(0.308 * 100)\% = 30.8\%$

Thus there is a mass gain of 30.8%

● Contours of constant mass gain or loss calculated using equation $\left(\tau_i^{\,j} = \left(\frac{C_j{}'}{C_j{}^o}\right)\left(\frac{C_i{}^o}{C_i{}'}\right) - 1\right)$ appear as horizontal lines, where $\tau_i^{\,j}$ is the fractional change in mass for species j relative to $C_j^{\,0}$ and $C_j{}'$ are the concentrations of the species in precursor and altered rock respectively.

● The gain of Mn,Y, and heavy REE are obvious as are the losses of Ba,Pb,Ta,Cu,Cr,Th and Sm. Gains of volatiles -Si, Mg, Ca,Sr are also indicated.

4. Conclusion

Mass balance analysis is very crucial for mass transfer mechanisms. Concentration diagrams provide significant information about bulk mass gain or loss as well as mass change of the individual components. Mass balance analysis can be correlated with observed modal changes in the rock to provide a record of the metamorphic history of the rock.

"THE IMPORTANCE of MEASUREMENT OF MAGNETIC SUSCEPTIBILITY IN A ROCK CORE"—'A GEOPHYSICAL APPROACH TO THE ANALYSIS OF STRUCTURAL & MINEROLOGICAL IDEAS ABOUT A ROCK'

SURANJAN GHOSH
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INTRODUCTION:

Magnetic Susceptibility is a quantitative measure of the extent to which a material may be magnetized in relation to a given applied magnetic field. The magnetic susceptibility of a material commonly symbolized by X_m is equal to the ratio of the Magnetization M within the material to the applied magnetic field strength H or $X_m = M/H$.

Magnetic minerals may be divided in three classes, Diamagnetic materials, i.e. when placed in the external magnetic field, partly expel the external field from within themselves & are characterized by the constant small negative susceptibilities, only slightly affected by changes in temperature.

Paramagnetic materials increase a magnetic field in which they are placed because of having their atoms with small magnetic dipole moments that partly line up with the external field. Paramagnetic susceptibility is inversely proportional to the value of the absolute temperature.

Ferromagnetic materials, do not have constant susceptibities, the magnetization is not usually proportional to the applied field strength. In such materials, the magnetization may be more than 1000 times larger than the external magnetizing field, because such materials are composed of highly magnetized clusters of atomic magnets that are more easily lined up by the external field.

The earthly materials like the rocks of various origins are found in nature that shows variation in their magnetic susceptibility value, depending upon the magnetic minerals present in the rocks. The following table shows the compiled values of some of the rocks of various origins.

Rock types	***Maximum volume Susceptibility (SI Units)***
Basalt	0.18
Granite	0.05
Average global igneous rocks	0.27
Average acidic igneous rocks	0.082
Average basic igneous rocks	0.12
Peridotites	0.20
Conglomerate/arkoses/pelites	0.0012
Arenites/breccias	0.0012
Average global sedimentary rocks	0.05
Gneiss	0.025
Granulites	0.03
Schist	0.003
Banded Iron Formation (hem. rich ~7% Magnetite)	0.25
BIF~20-25% or more Magnetite	1.8
Average global metamorphic rocks	0.073
Magnetite minerals	5.7

Thus, based on this property some of the geophysical properties of the rocks can be analyzed. Though that are not very essential for the geological study, but they give a support to the geological interpretations we made in their own way.

The most widespread use of this magnetic susceptibility in geophysics is in the domain of Anisotropy of magnetic susceptibility and magnetic mineralogy of the rocks of any origin using their susceptibility values.

"Anisotropy of magnetic susceptibility & it's application in the study of magnetic foliation, lineation, magma Flow in dykes"

Dyke intrusion is considered a common form of magmatism at composite volcanoes, even though the active process cannot be directly observed and must be inferred from the geophysical data or exposed outcrops. But the orientation of individual dykes reflects the stress field at the time of intrusion, and the dyke-swarms is manifested at the surface by a pattern of flank eruptive vents. Determining if such dykes intrude laterally, vertically or obliquely is important for characterizing future eruptive behavior of the host volcano.

The anisotropy of magnetic susceptibility (AMS) technique has proved to be a valuable tool for defining magma flow directions in tabular intrusions such as dykes or sills.

Two general models describe the relationship between magma flow direction and principle susceptibility axes. The classical application of the AMS technique to igneous rocks assumes that the magnetic lineation or the mean of the K2 axes is parallel to the magma flow vector.

In the second model, the flow vector is estimated from the geometric computation between the K3 axes and the pole of the intrusion wall, as K1 often results in an intersection axis i.e. the zone axis of sub-fabrics.

In the cases of abnormal magnetic fabrics with K1 axes not coincident with the magma flow direction or when K1 and K3 axes and symmetry are inverted, the relationships between crystal orientations, magma flow direction, and principle susceptibility values can be explained by:

(a) Single domain effects of magnetic crystals;

(b) Late growth of ferromagnetic minerals in a direction perpendicular to the dyke-wall;

(c) Rolling effects on large grains

(d) Turbulent flow.

Theory:

The AMS technique is based on the measurement of the variation of susceptibility in a standard volume of rock when a weak magnetic field ($d < 1$ mT) is applied in different directions. Such a variation can be described mathematically by means of a second-rank symmetric tensor, which can be physically expressed as an ellipsoid whose principal axes represent the three principal susceptibilities (maximum, intermediate and minimum susceptibility axes, or $K1 > K2 > K3$).

With independence of the source of the magnetic susceptibility (ferromagnetic, paramagnetic or diamagnetic minerals), it has been demonstrated that the magnitude of this anisotropy depends on two factors:

(a) the magnetic anisotropy of the particles themselves and

(b) the degree of their alignment.

The preferred orientation of crystallographic axes (crystalline anisotropy) determines the AMS for the majority of minerals (mainly in paramagnetic minerals and hematite). In the case of magnetite, the AMS is controlled by the shape preferred orientation of individual grains or grain aggregates (shape anisotropy). The respective contributions of the paramagnetic (silicates) and ferromagnetic (magnetite and other Fe–Ti Oxides) phases to the whole AMS depend on both the intrinsic susceptibility of the minerals and on their concentration in the rock.

Many parameters are classically used globally to describe the AMS fabric of rocks. In this study the following parameters to characterize the magnitude and shape of the susceptibility ellipsoid are used (Jelinek, 1981; Hrouda, 1982):

Corrected anisotropy degree:

$P_j = \exp [2(5fb_1 - 5fb_m)^2 + (5fb_2 - 5fb_m)^2 + (5fb_3 - 5fb_m)^2]^{1/2}$

Where, $5fb_1 = \ln K1$; $5fb_2 = \ln K2$; $5fb_3 = \ln K3$ and $5fb_m = (5fb1 + 5fb2 + 5fb_3)/3$*Shape parameter

$T_j = [^{2\ln (K2/K3)}/_{\ln (K1/K3)}]^{-1}$

The Pj parameter is used to quantify the degree of magnetic Anisotropy and Tj characterizes the shape of the AMS ellipsoid. In addition to these parameters, we also use the bulk magnetic susceptibility. i.e.

$K_m = (K1+K2+K3)/_3$,

Magnetic lineation (L) = $^{K1}/_{K2}$

Magnetic Foliation (F) = $^{K2}/_{K3,}$ and

The anisotropy ratios of L against F.

We also use the parameters P_j and T_j to represent the symmetry of shape ($-1<T<+1$, $T>0$ for disk shapes and $T<0$ for rod shapes) and the eccentricity of the ellipsoid, respectively as defined by Hroud (1982).

In rocks, AMS is chiefly governed by several factors including (1) orientation of the grins i.e. shape anisotropy, (2) distribution of the grains i.e. distribution anisotropy & (3) alignment of the magnetic domains i.e. domain anisotropy. It is generally considered that AMS is flow related when the magnetic foliation is closely parallel to the dyke plane, whereas in contrast the relationship between magnetic lineation and the magma flow is questionable, and both parallelism and orthogonality of K1 with respect to the flow direction.

Concept of Magnetic Foliation:

The Magnetic anisotropy of foliated rocks of several types has been measured by the torque-meter method, and shows that the alignment of long axes of the magnetic grains normally follow the pattern of foliation is evident in field observations. In a sharp fold in lit-par-lit formation the magnetic anisotropy indicated an otherwise undetected lineation independent of the bedding and superimposed upon the foliation determined by the layering.

Magnetic foliations close to the northern and southern margins of the pluton are similar to the mesoscopic foliations of the surrounding gneisses (Pratheesh et al., 2013). The orientation of magnetic- foliation can also be used to distinguish among different structures, sills and dykes, a task sometimes impossible simply by field observations (Halverson 1974).

Concept of Magnetic Lineation:

Rock fabrics can reflect the strain state of rocks and are a rich source of information of tectonic evolution. Lineation is a common fabric element in rocks and is particularly useful in deciphering the history of deformation. Lineation is commonly defined as any linear feature that occurs penetrative in a rock and includes form lineation's (crenulations, rods, and elongate pebbles) and mineral elongation (stretched grains, linear aggregates of equi-dimensional grains, sub-hedral grains with an elongate crystal shape, etc.). Lineation introduces anisotropy in the physical properties of rocks and therefore it can be determined by methods capable of sensing rock anisotropy.

The most obvious means of determining the origin of magnetic lineation in deformed rocks is to obtain AMS records from rocks deformed in different tectonic environments in order to compare the magnetic anisotropy tensor and its axes distribution with the structural elements (Joseph M Pares, etal., 2002).

Description of the Instrument used & the methodology of the data receiving:

AMS was measured with a KLY-2.02 susceptibility meter (using a bridge at low magnetic field), which is based on measuring the directional susceptibilities corresponding to 15 suitable directions in the rock specimens. The averages (arithmetic mean) of AMS data for all sites are used for analysis.

Details of the instrument is given below-

Magnetic Susceptibility Meter - Model Kappa bridge KLY-2;

Vendor: Geofyzikan.p. Brno Czechoslovakia

Software: anisoft20

Vendor Manual: Instruction manual for Magnetic Susceptibility Bridge KIM-20R Computer Interface Module

a. Introduction of the instrument:

The Kappa Bridge Kly-2 is designed for measuring the magnetic susceptibility and anisotropy of hard rock or sediment samples. The kappa bridge KLY-2 magnetic susceptibility system measures MS and AMS of hard rock or sediment samples at sensitivities of 0.05 x 10^{-6} SI unit to 200,000 x 10^{-6} SI unit within a series of 11 ranges. The instrument's operation is based on measurements of inductivity changes in a coil due to a rock specimen. The software package includes tensor calculation and statistics, graphic data display and printout, and data storage. It's high accuracy, fast measuring rate, and outstanding sensitivity makes it possible to measure rocks with very weak magnetic properties. Sensitivity amidst magnetically noisy surroundings. Thus, the location of the sensor is an important factor when using the kappa bridge. Avoiding placement of the sensor near computer terminals, other instruments and metal fixtures will definitely improve its performance.

b. Measuring Samples

Set Range selector to 5 (if specific Range not previously known) and be sure both the Im and Re are zeroed. Then, if the bridge is in the status WAIT, wait until it converts to the status READY by automatic zeroing.

Press the button START/RESET; so that the bridge enters the status MEASURE. Insert the specimen into the pick-up coil as quickly as possible.

After the beep sounds, remove the specimen from the pick-up coil and wait for a few seconds after which the bridge enters the status HALT. If blinking 1999 appears in the display DATA, the bridge is overloaded and the measurement must be repeated in a higher range. But if the display does not blink, decide whether the correct measuring range has been selected (Range correction factors taped to the bridge) and adjust accordingly.

c. Sample orienting and anisotropy of Magnetic susceptibility value measuring techniques

During measurement process, the susceptibility of the specimen is measured subsequently in 15directions following the rotatable Jelinek's design in exactly the same way as in the KLY-2, KLY-3 andKLY-4 Kappa bridges. Using the least squares method, the susceptibility tensor is fit to these measurements of the 15 directional susceptibilities and the errors of the fit are calculated.

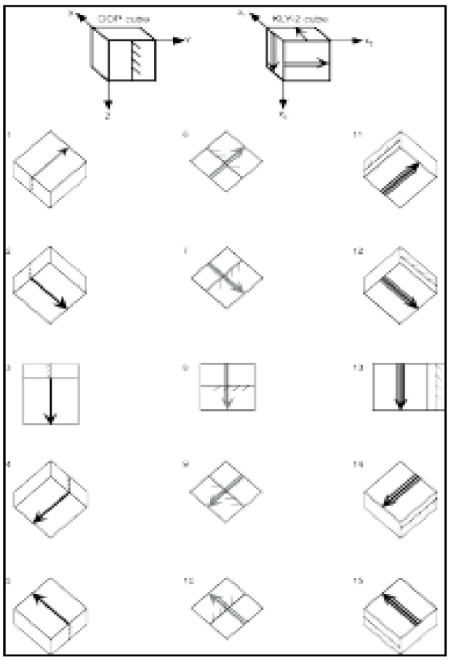


Figure: 1 Orientations of each specimen that are needed to be measured for each of the cores used in the anisotropy of Magnetic susceptibility.

Interpretation of some measurements:

AMS analyses were performed on some of the basement granites. Granite of that area is mainly coarse-grained porphyritic granite, grayish in color though sample AMS210 is pink in variety. Magnetic fabric analyses of the 21 oriented granite samples were carried out.

The mean bulk susceptibility (K_m) values in the samples are in general low<300 X 10^{-6} SI unit, indicate presence of paramagnetic minerals. Amongst 21 sample 5-granite samples (AMS205, AMS212, AMS206, AMS220 and AMS227) shows very high susceptibility value varying from 1190 X 10^{-6} to 8630 X 10^{-6} SI units, which implies the ferromagnetic minerals, may contribute to the susceptibility and to its anisotropy.

Therefore, the temperature variation susceptibility analyses on those 5 samples (AMS205, AMS212, AMS206, AMS220 and AMS227) giving high K_m values as well as some others representing (AMS201A, AMS203, AMS207, AMS210, AMS213A and AMS222) granite samples having lower K_m values may help to get an idea about the magnetic mineralogy of the rocks.

The values of variable AMS parameters of the representative low and high susceptibility granite samples are given in the following tables respectively as measured in Kappa-Bridge KLY-2.

Sample No.	Rock Type	No. of Cores	Km (x 10-6 SI units)	Pj	T	K1 D/I	K2 D/I	K3 D/I
AMS203	Granite	6	93	1.047	0.688	325.2/1.7	199.8/87.1	55.3/2.4
AMS207	Granite Gneiss	6	245	1.047	-0.037	154.8/5.9	59.2/43.4	250.9/46
AMS210	Pink Granite	5	143	1.013	-0.077	147.1/23.4	345.8/65.5	240.1/7
AMS213A	Granite	6	83.1	1.026	0.242	189.5/14.9	294.7/44.7	85.9/41.5
AMS222	Granite	5	88.8	1.012	0.286	194.9/8.8	103.2/11.1	322.6/75.8

Sample No.	Rock Type	No. of Cores	Km (x 10-6 SI units)	Pj	T	K1 D/I	K2 D/I	K3 D/I
AMS205	Granite	6	2970	1.215	-0.036	147.1/23.4	222.8/58	13.7/28.6
AMS206	Granite Gneiss	5	7610	1.49	0.353	152/2.8	352.2/87	242/1
AMS212	Granite	6	1340	1.127	0.167	139.9/6.5	41.4/52.4	234.8/36.8
AMS220	Granite	6	8630	1.188	-0.146	101.9/26	252.5/60.8	5.7/12.4
AMS227	Granite	6	1190	1.089	0.316	40.7/62.1	187.3/23.8	283.5/13.6

In the above data sheet, K_m = Mean susceptibility; L = strength of magnetic lineation; F = strength of magnetic foliation; P_j = corrected degree of magnetic anisotropy; T = shape of AMS ellipsoid (+ve = oblate & -ve = prolate).

K_1 and K_3 are Declination/Inclination of the Maximum and Minimum principal axes respectively of the AMS ellipsoid; Note: K_1 is the orientation of the magnetic lineation and K_3 is pole to the magnetic foliation (K_1K_2) plane.

Again it can be interpreted from the sheet that, P_j value varies between 1.004 - 1.666. The K_m vs. P_j plot indicates increase in P_j value with increasing the mean susceptibility (K_m), though there is no one to one direct relationship between K_m and P_j.

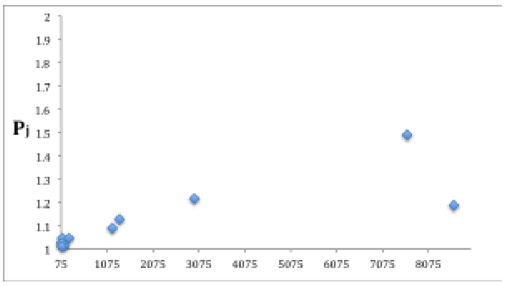


Figure: K_m vs. P_j plot showing with increasing K_m value P_j Value is also increases.

The shape parameter T ranges between -0.804 to + 0.952 i.e. both negative as well as positive values implies prolate and oblate shape of the susceptibility ellipsoid respectively.

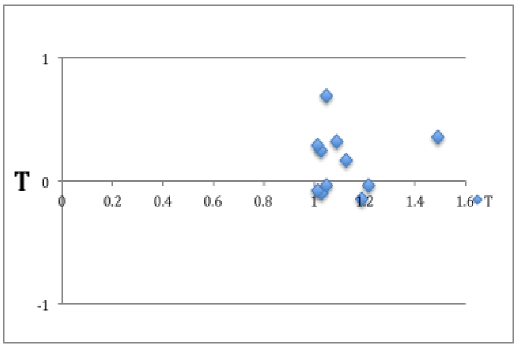


Figure: Degree of magnetic anisotropy Pj vs. shape parameter T plot (Jelinek plot)

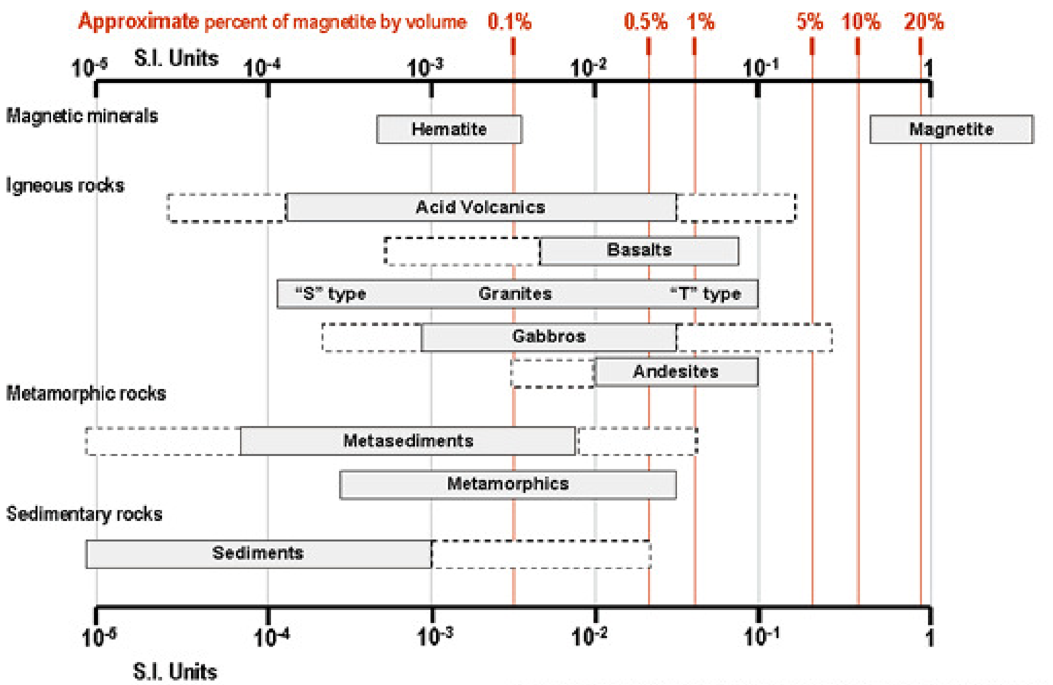
There is variation in orientation of magnetic foliation and lineation. The dominant orientation of magnetic foliation is NW-SE sub-vertical; others are showing N-S to NNE-SSW and NE-SW. The lower hemisphere equal area projection diagram shows that the mean orientation of the entire magnetic foliation of the study area trending NW-SE, more or less sub-vertical dipping similar to that of the observed field foliation.

The second most important use of the magnetic susceptibility of the individual rocks and minerals are in the identification of their magnetic property, mineralogy and the analysis of their magnetic mineral contents.

Magnetic minerals are widely present in Earth's crust in a good amount. Hence during the formation of each of the Igneous, Metamorphic or sedimentary rocks they become a part of them in their chemical composition. Kappa Bridge is a very sensible instrument that has the capability to identify the presence of even the slightest of the magnetic minerals presence. Hence their well abundance in any rock may induce a change in the magnetic susceptibility value. Thus an overall scenario of their presence in percentage (%) & the susceptibility value is shown in the diagram.

Description of the Instrument used for the thermal susceptibility analysis & the methodology of the data receiving:

The magnetic susceptibility variation with temperatures is measured using Kappa Bridge KLY-2 attached with CS-3. The CS-3 (High Temperature Apparatuses) has been designed for measurement in connection with KLY-2. The CS-3 High Temperature Furnace Apparatus is used for measurement of the



Adapted from Clark and Emerson, Exploration Geophysics, 1991.

temperature variation of low-field magnetic susceptibility of minerals, rocks and synthetic materials in the temperature range from ambient temperature to 700 °C.

The method of magnetic mineralogy analysis of any rock is done by using its core (in case of hard rock) or a cube of samples in case of soft rocks or dusts or soil particles is thermal susceptibility measurement using Kappa Bridge.

Geological Institute

The apparatus consists of non-magnetic furnace with a special platinum thermometer, CS-3 electronic temperature control unit, and cooling water reservoir with pump, and argon flow meter.

The specimen is placed in a measuring vessel, which is heated by a platinum wire in three selectable heating rates. The temperature is measured by special platinum thermometer. The protective argon atmosphere can be applied during heating to prevent oxidation of measured specimen. In order to perform susceptibility measurement at a chosen temperature range, the equipment moves automatically the furnace into and out of the pick-up coil of the Kappa Bridge. The quasi-continuous measurement process is fully automated, being controlled by the software.

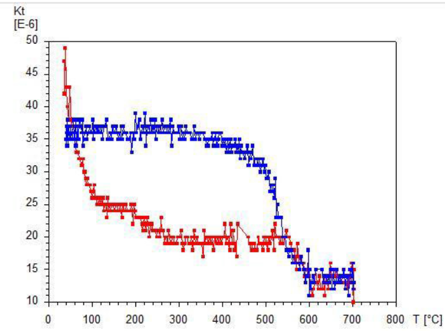
Magnetic Mineralogy analysis:

It is known that paramagnetic, diamagnetic and ferromagnetic minerals contribute to the rock susceptibility and to its anisotropy (Rochette et al., 1992; Tarling and Hrouda, 1993). As shown in Table, a number of the granites are paramagnetic with K_m<500SI. This implies that paramagnetic minerals such as biotite and hornblende are responsible for the AMS in these granites. In contrast, the AMS in the ferromagnetic granites (K_m>500SI) is expected to be controlled by ferromagnetic minerals such as magnetite.

Temperature variations of magnetic susceptibility (8–T) investigations were done to evaluate the magnetic mineralogy of the paramagnetic and ferromagnetic granites. 8–*T* investigations were done on powdered samples, using the CS-3 furnace (from room temperature to 700°C) attached to the KLY-2 Kappa Bridge in the magnetic laboratory of IIG, Allahabad. 8–*T* studies of paramagnetic granites do not show any significant drop in the magnetic susceptibility at 580°C (Curie *T* of magnetite) in the heating experiments. This indicates the absence of magnetite in dominant amount in the paramagnetic granites. 8–*T* studies of these high-susceptibility granites show a sharp drop in the susceptibility at 580°C in the heating experiments. This is the Curie *T* of magnetite and thus the presence of the latter mineral is confirmed in the high-susceptibility samples.

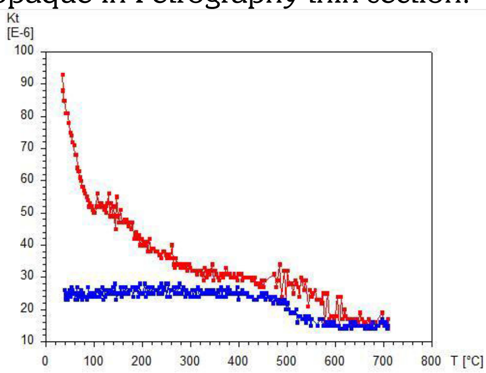
Analysis of some Granite Samples:

The temperature dependent magnetic susceptibility values were measured using Kappa Bridge KLY-2 with CS-3 temperature control interface unit for some selected granite samples with maximum and minimum magnetic susceptibility values measured previously from the above table values. Following results were found in the form of some diagrams from the ANISOFT software that is used in the interpretation of the analysis.



AMS207

The temperature dependent susceptibility curve shows that paramagnetic grains mainly dominate the granite sample, which is also later verified by petro graphic analysis. Also, as it is evident from the fall in ê-T curve at temperature around 550^0c,some ferromagnetic minerals in minor amount is present that is possibly weathered hematite, which appears as opaque in Petrography thin section.

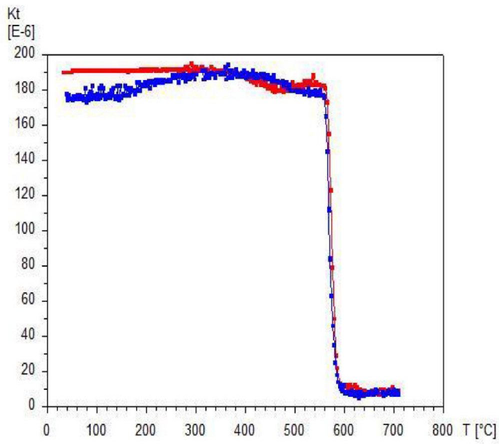


AMS210

The temperature dependent susceptibility curve shows that paramagnetic grains mainly dominate the granite sample. The Petrography analysis suggests the predominance of orthoclase, plagioclase grains with some quartz grains, identified by their petrologic textures.

AMS206

The temperature dependent susceptibility curve shows that



AMS220

ferromagnetic grains mainly dominate the granite sample. Since there is a sharp fall in the heating curve and rise in cooling curve at around 580^0c, which is the Curie temperature for magnetite. Hence ferromagnetic grains of magnetite are supposed to be present that appear in petrologic thin section as inclusions of opaque in quartzo- feldspathic grains.

The temperature dependent susceptibility curve shows that ferromagnetic grains with some paramagnetic grains mainly dominate the granite sample. Since there is a sharp fall in the heating curve and rise in cooling curve at around 580^0c, which is the Curie temperature for magnetite. Hence ferromagnetic grains of magnetite are supposed to be present that appear in petrologic thin section as inclusions of opaques in quartzo - feldspathic grains and also along the fracture of the grains.

Conclusions:

The magnetic mineral assemblage may reflect not only the conditions of granite formation, but also processes of its later evolution whereby its magnetic mineralogy may change. Consequently, the susceptibility must be used as granite origin indicator with great caution, after a thorough study of the origin of magnetic minerals. Nevertheless, as the susceptibility measurement is much faster and cheaper than the investigation of oxygen and strontium isotopes used for the discrimination of the granite type in geochemistry, the susceptibility study can be recommended as a support for petrologic analysis of magnetic mineralogy.

Thus it can be inferred that the susceptibility property of magnetic minerals is very essential and a matter of great importance to geophysical analysis because it gives idea about the foliation – lineation from the Structural geology as well as mineralogical ideas. Thus as a petro-structural analyzer this is a matter of great importance to the geological analysis, especially for outcrops dominate with massif litho units.

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INFLUENCE OF HUMAN ACTIVITIES AND VARIATION OF SEDIMENT DISCHARGE OF LARGE INDIAN RIVERS

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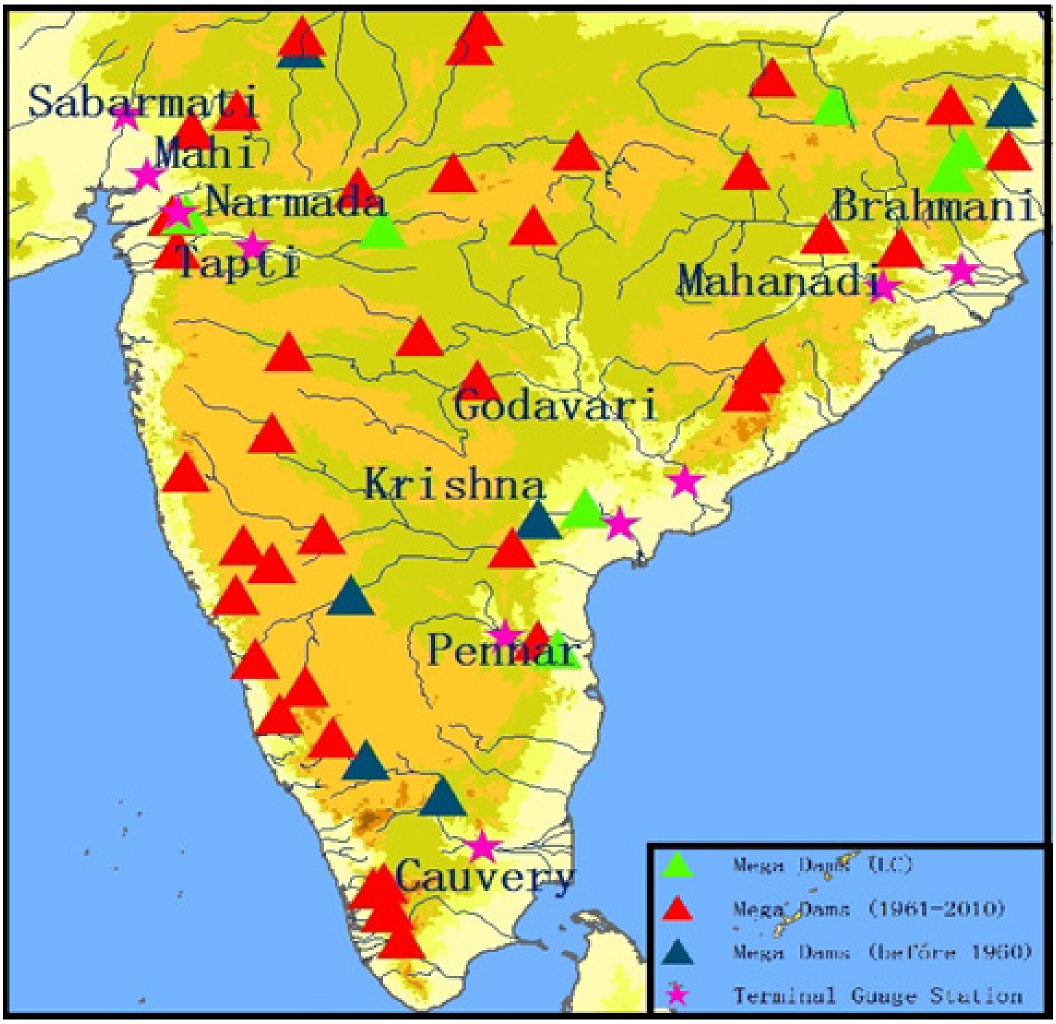
It is evident that geological processes relentlessly change the face of the Earth, but we pay less heed to a second type of process of change, extremely recent if considered at geological time scale, consists of the permanent activities by human being. The term "Anthropocene" has been introduced for the current geological epoch to emphasize the central role of humankind in geology and ecology. The Anthropocene is being considered as a defined geological epoch, wherein the human species has collectively impacted the Earth's surface so as to result in a global signal in the permanent geological record. Change in global climate through greenhouse gas emission and rate of material transport by rivers, could be taken as two most discernable examples of human induced environmental impacts.

Humans have both increased the erosion of the landscape and intercepted the sediment along the hydrological pathways, sometimes simultaneously, sometimes in sequence. The major means for increasing a river's sediment load is through mining, deforestation, conversion of pastureland to cropland, poor farming practices and through road construction. Increased soil erosion led to increased sediment fluxes in most of the rivers across the globe and it was proposed that due to growing human activities, natural processes of soil/sediment erosion have been accelerated, perhaps by a factor of two on a global scale.

In this modern era of rapid human-caused changes, driven by a need to cope with the growing demand of food and energy, both for agriculture and industrial needs, tens of thousands of dams have already been constructed and several thousand more are planned across the globe. It has been shown that dams trap a significant proportion of the global sediment fluxes, that would otherwise be delivered to the oceans and this number appears to be steadily increasing. It is obvious that human actions persistently change the trends of the suspended loads in the world's rivers and with the growing human activities, much has changed in terms of sediment delivery with variances in both directions.

On the global scale, Asian rivers have been recognized as the largest sediment supplier (6300 MT) to the world's oceans (14,000 BT). Historical studies suggested that rivers draining Indian sub-continent collectively deliver 2500 MT of suspended sediment annually; accounting for 15-20% of the global sediment flux. However, similar to other large global rivers, most of the Indian rivers (including the Ganga) have been regulated in the last few decades and declines in downstream sediment loads have already been reported. Despite this well understood fact, a recent study by Panda et al. (2011) relates the sharp decline in annual sediment loads of the most peninsular rivers with climatic factors (such as decline in rainfall). Based on trend analysis, here we evaluate large peninsular rivers for annual rainfall, water discharge and sediment load.



Indian sub-continent experiences monsoon climate and densely populated. It is obvious that sediment discharge responds both to the impact of humans and to changes in climate. Some of recent studies have shown change in rainfall patterns and increase in intensity of extreme rain events (Goswami et al., 2006). It might influence the sediment discharge patterns of Indian rivers, however there are not sufficient evidences to support this argument. At other hand growing number of global, regional and basin scale studies are showing retention of huge amount of sediments behind dams. Trend analysis of annual rainfall, water discharge and sediment load for these eight rivers suggest that except Brahmani, Mahanadi and Tapti, none of the other rivers show any significant positive trend in annual rainfall. Surprisingly, despite showing increase in rainfall these three rivers showed decline in annual water discharge. Only Penner river showed increase in annual water discharge, which is due to inter-basin water transfer. Indian peninsular region hosts about 3700 large and 40 mega dams and our results further suggest that construction of these dams undisputed resulted in decline in sediment flux to costal seas.

বঙ্গোপসাগর অভিযান—অধ্যাপক সুপ্রিয় দাস এর সাক্ষাৎকার

বিদিশা দে, স্নাতকোত্তর, দ্বিতীয় বর্ষ

এই বছরের প্রথমদিকে আন্তর্জাতিক মহাসাগরীয় ড্রিলিং প্রকল্পের (International Ocean Drilling Program; IODP) একটি অভিযানে গিয়েছিলেন আমাদেরই বিভাগের অধ্যাপক, ড. সুপ্রিয় দাস। কেমন ছিল সেই অভিজ্ঞতা? কিভাবে গেলেন সেখানে? এইসব প্রশ্নের উত্তর জেনে নিতেই গিয়েছিলাম তাঁর কাছে। সেই সাক্ষাৎকার তুলে দিলাম আপনাদের কাছে।

বিদিশা ঃ IODP-র এই প্রকল্পের সম্পর্কে আপনি প্রথম জানলেন কিভাবে?

ড. সুপ্রিয় দাস ঃ আমি যখন বিদেশে পোষ্ট ডক্টরাল গবেষণা করছি তখন IODP-র কাজকর্ম সম্পর্কে জানতে পেরেছিলাম, এটাও জানতাম যে IODP-র একটা অভিযান বঙ্গোপসাগরে হবে। কবে হবে সেটা জানতাম না।

ভারতে ফিরে এসে জানতে পারলাম এটা হতে চলেছে ২০১৫-তে এবং NCAOR (National Centre for Antartic and Ocean Research) এর মাধ্যমে আবেদন করতে হবে। আমি আমার যোগ্যতা, গবেষণার বিষয় এবং ভারতের জন্য কাজ করবার আগ্রহ জানিয়ে আবেদন করি। আমার আবেদন আন্তর্জাতিক IODP কমিটি মঞ্জুর করে এবং আমি ভারতীয় জৈব ভূ-রসায়নিক হিসাবে অন্তর্ভুক্ত হই।

বিদিশা ঃ এইরকম কোন অভিযানে যাওয়ার সুযোগ কি আমরাও পেতে পারি?

ড. সুপ্রিয় দাস ঃ হ্যাঁ এই ধরনের সুযোগ তোমরাও পেতে পার। শুধু IODP নয়, ভারতীয় আন্টার্কটিকা অভিযান সেখানে স্নাতক ও স্নাতকোত্তর স্তরের ছাত্ররা আবেদন করতে পারে। supervisor এর একতা সম্মতি লাগবে ও সাথে গবেষণার প্রস্তাবনা জমা করতে হবে।

বিদিশা ঃ এবার এই অভিজ্ঞতা সম্পর্কে যদি কিছু বলেন।

ড. সুপ্রিয় দাস ঃ এটা এমন একটা অভিজ্ঞতা যেটা আর কোন রকম ভাবে সম্ভব নয়। একটা জাহাজ যাতে গবেষণার সমস্ত রকমের ব্যবস্থা আছে, সেই জাহাজে বসে কাজ করা বা তথ্য বিশ্লেষণ করা একটা বিশাল বড় অভিজ্ঞতা। আর এখানে সারা বিশ্বের নামী ভূবৈজ্ঞানিকদের সাথে কাজ করা একটা বড় অভিজ্ঞতা।

জাহাজে সাধারণত ১২ ঘন্টার কাজ করতে হয়। একটা নির্দিষ্ট স্থানে, সে গবেষণাগারে হোক কি ড্রিলিং প্লাটফর্ম হোক, সেই ১২ ঘন্টা থাকতে হবে। এটা খানিকটা কষ্টকর কারণ ১২ ঘন্টা টানা কাজ করতে হচ্ছে, কিন্তু বেশ মজার কারণ সবাই একই কাজ করছে, এই একসাথে কাজ করাটা একটা দারুণ অভিজ্ঞতা।

আমার কাজ ছিল মিথেন পরিমাপ করা। সমুদ্রের তলা থেকে মাটি তোলা হলেই ডাক পড়ত এবং সঙ্গে সঙ্গে তার পরিমাপ করতে হত।

বিদিশা ঃ এর আগে কি আপনার এই ধরনের কোন অভিজ্ঞতা ছিল?

ড. সুপ্রিয় দাস ঃ হ্যাঁ এর আগে আমি যখন PhD করি তখন ২ বার অ্যাটলান্টিক এ জাহাজে চড়ে গবেষণার জন্য নমুনা সংগ্রহ করেছি, সেটা একটা অন্য ধরনের গবেষণা। কিন্তু প্রত্যেকটা অভিযানের অভিজ্ঞতাই আলাদা। IODP বা অন্য কোনও অভিযান-এ যাওয়ার জন্য কোন পূর্ব অভিজ্ঞতার প্রয়োজন হয় না।

বিদিশা ঃ ড্রিলিং চলাকালীন এই জাহাজটা কি একই জায়গায় স্থির থাকে? এর ওপর ঢেউয়ের কোন প্রভাব পড়ে কি?

ড. সুপ্রিয় দাস ঃ IODPর জাহাজ দোলে না। এই জাহাজটার ১২টা থ্রাস্টার (Thruster) আছে, যার সাহায্যে জাহাজটা একই জায়গায় স্থির থাকে। কারণ যখন সেটা ড্রিল করছে, ৩-৩.৫ কি.মি. জলের নিচে আরো ১-১.৫ কি.মি. তলা পর্যন্ত ড্রিল করা

হচ্ছে। এই সেটিংটা তখনই ঠিক ভাবে থাকবে যখন জাহাজটা একদম একই জায়গায় থাকবে। এটা যদি ৫-১০ মিটারও এদিক-ওদিক করে তাহলে পুরো ব্যাপারটা ভেঙ্গে যাবে। আর এই ড্রিল করাটা বেশ খরচ সাপেক্ষ, এক-একটা অভিযানে ৬০ মিলিয়ান ডলার এর মত খরচ হয়; সিঙ্গাপুরে জাহাজের তেলই ভরা হল প্রায় ১৫ মিলিয়ান ডলারের।

বঙ্গোপসাগর এমনিতে খুবই শান্ত, ডিলিং চলাকালীন বোঝা যেত না যে জাহাজে আছি। তবে যেটা সমুদ্রের মাঝে গিয়ে সমস্যা হয় যে একদমই কোন সবুজ দেখা যায় না। চারিদিকে খুব সুন্দর নীল জল, কিন্তু আর কোন কিছু চোখে পড়ে না। জাহাজের ভিতরে আমরা মোট ১২০ জন মত লোক ছিলাম তারা ছাড়া, আর কারো সাথে দেখা হবার কোন সম্ভাবনা নেই। একসময় এমন হত যে দূর দিয়ে কোন মালবাহী জাহাজ গেলেও খুব আনন্দ হত।

বিদিশা ঃ এই রকম একটা পরিবেশে জাহাজে থাকার দৈনন্দিন অভিজ্ঞতা কেমন?

ড. সুপ্রিয় দাস ঃ জাহাজে থাকাকালীন নিয়মিত প্রত্যেক রবিবার আপৎকালীন অনুশীলন হত। যদি জাহাজে কোন দুর্ঘটনা ঘটে, তাহলে যাতে জাহাজ ছেড়ে পালাতে পারি সময়মত সেইজন্য। এতে যেতেই হতো, খুব যদি কেউ ক্লান্ত থাকত বা সবে ঘুমোতে গেছে এরকম ক্ষেত্রে অবশ্য ছেড়ে দেওয়া হত।

ড্রিল এ আমাদের লাইন করে দাঁড় করিয়ে একটা লাইফবোট এ উঠিয়ে দেখানো হয় যে কোথায় জল আছে কোথায় খাবার আছে ইত্যাদি। এখানে একটা অদ্ভূত জিনিস জানতে পারি, যে জল না খেয়ে মেয়েরা ছেলেদের থেকে বেশি বেঁচে থাকতে পারে।

এই ড্রিল এ একদিন আমি খুব দেরি করেছিলাম, আসলে আমি ঘুমোচ্ছিলাম আর ড্রিলের সময় সবাইকে ডাকার জন্য একটা অ্যালার্ম বাজে, তো এই অ্যালার্ম এর আওয়াজ এ খুব বিচ্ছিরি রকম ভাবে ঘুমটা ভেঙ্গে যায়। এবং ঘুম থেকে ওঠার পর মনে হয় আমি কোথায় আছি, কি করছি? কেন কিছু মনে পড়ে না। যখন মনে পড়ল তখন তাড়াহুড়ো করে ওপরের বার্থ থেকে নেমে জুতো-টুতো খুঁজে হেলমেট নিয়ে গিয়ে দাঁড়িয়েছিলাম অন্য লাইনে যেখানে আমার যাবার কথা নয়। অনেকক্ষন পরে একজন বলল তুমি এখানে কেন? জাহাজের যে ফার্স্ট মেট তার হাতে দায়িত্ব ছিল জাহাজের সুরক্ষার, তো সে আমাকে অনেক বকাবকি করল, তখন পাশ থেকে আমার এক আমেরিকান বন্ধু চুপি চুপি বলল, 'চিন্তা করিস না, জাহাজ ডুবলে ফার্স্ট মেটের দায়িত্ব তোকে খুঁজে বার করা; নাহলে ওর জেল হবে। চাকরি যাবে।" সেটা ফার্স্ট মেটের কানে পৌঁছায়নি ভাগ্যিস। মানে ফার্স্ট মেটের দায়িত্ব যেহেতু সুরক্ষা, জাহাজ যদি সত্যি কোন বিপদে পড়ে সে তো আমাকে ছেড়ে যেতে পারবে না। তাকে ফিরে এসে সমস্ত কেবিনে খুঁজতে হবে।

আমাদের জাহাজের কর্মচারী সবাই ইন্দোনেশিয়ান ছিলেন যদিও ক্যাপ্টেনও ফার্স্ট আমেরিকান ছিলেন। জাহাজটা আমেরিকার। আমাদের সবারই কাজের সময় ভাগ করা থাকত। আমার সঙ্গে কেবিনে থাকতেন একজন চিনা ভদ্রলোক। তার যখন কাজের সময় ছিল তখন আমার ঘুমানোর সময়। এই ভাবে ২৪ ঘন্টাই কেউ না কেউ কাজ করত, আর কেউ কাউকে বিরক্ত করত না।

এই জাহাজে সবাই মিলে খুব আনন্দ করতাম, যখন বৃষ্টি হত না তখন জাহাজের ডেকে পিকনিক হত।

ওখানে একটা মাল্টিজিম ছিল, একটা পুল ছিল, অনেকরকম খেলার জায়গা ছিল, সিনেমা হল ছিল, জাহাজে মদ্যপান মানা ছিল। একটা রেস্তরাঁ ছিল যেখানে প্রতি ২ ঘন্টায় গরম খাবার পাওয়া যেত। কিন্তু কিছুদিন পর এইসব খাবার খুব একঘেয়ে হয়ে গিয়েছিল; তাই একটা সময়ের পর আমি শুধু কর্নফ্লেক্স খেতাম। তবে তার মানে এই নয় যে আমি রোগা হয়ে গেছিলাম। অভিযনে সবাই মোটা হয়, কারণ যখন কেউ সারাক্ষণ কাজ করছে আপনজনেদের থেকে দূরে আছে তখন সে খানিকটা বিষণ্নতায় ভেসে, আর তার ফল হিসেবে সবাই একটু বেশি খায় এবং একটু মোটা হয়ে যায়।

জাহাজের গবেষণাগারের টেকনিশিয়ানরা বেশিরভাগ আমেরিকান ছিলেন। এই টেকনিশিয়ানরা

অনেকেই মহিলা ছিলেন এবং সবার সঙ্গেই সমানভাবে কাজ করত। তারাও আর পাঁচজনের মতই সাধারণ মহিলা কিন্তু কারোও থেকে কোন অংশে কম নয়।

সব মিলে একটা খুব ভাল অভিজ্ঞতা। এমন একটা অভিজ্ঞতা যেখানে আমি আবার যেতে চাইব, এবং আমি সবাইকেই বলব যাতে তোমরাও আবেদন কর।

বিদিশা ঃ শেষ একটা প্রশ্ন করি যে আমরা আর কিছুদিন পরে কাজের জগতে ঢুকতে যাচ্ছি, তাদের প্রতি কি বলবেন?

ড. সুপ্রিয় দাস ঃ আমাদের, ভারতীয়দের অসুবিধা হল আমরা নিজেদের ঠিকমতো তুলে ধরতে পারিনা। এমন নয় যে আমরা ইংরাজি বুঝতে পারিনা বা খারাপ কাজ করি কিন্তু যে কাজটা করি সেটা ঠিকমতো উপস্থাপনা করতে পারিনা।

আর দ্বিতীয় হল যে আমাদের একটা ধারণা আছে যে ভাল কাজ শুধু বিদেশিরাই করে, সেটা ভুল। আমরাও ভাল কাজ করি এবং করছি আর সেটা জন্য আমাদের একটা আত্মসম্মান থাকা উচিত। সেটা যদি না থাকে তো বাইরে গিয়ে কোন স্বীকৃতি পাবে না। সবসময় মনে রাখবে যে বন্ধুত্ব বা প্রতিযোগিতা সমানে সমানে হয়। যদি সমান না হতে পারো তাহলে কোন লাভ নেই। এমন কাজ করতে হবে যেটা আমার জায়গায় দাঁড়িয়ে বেস্ট হয়। হতে পারে অন্য কেউ আমার থেকে ভালো কাজ করছে, কিন্তু সে আমার জায়গায় থাকলে যা করতে পারত তার থেকে যেন আমি ভাল করি। কাজকে ভালবেসে নয়, ভালবেসে কাজ করতে হবে।

TRUE ORIGIN OF HYDROCARBON-MYSTERY OVER THE DECADES

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Nature has been transmuting dead life into black gold for millions of years using little more than heat, pressure and time, scientists tell us. But with gas prices spiking more than $1 per gallon in the United States this year and some experts predicting that the end of oil is near, scientists still don't know for sure where oil comes from, how long it took to make, or how much there is. The origin of petroleum is a matter of debate from its discovery and a pending issue. Currently there are two theories can be called as biogenic and abiogenic model of formation. According to biogenic theory majority commercial interesting hydrocarbons has been expelled from sedimentary source rocks and trap in the reservoir rocks. While the current abiotic theory states that these hydrocarbons has been formed in deep origin of earth without any involvement deceased organic matter and sedimentary rocks has nothing to produce it and has been erupted from great depth (kenny 1996).

Biogenic origin of petroleum :

The beginning of 20th century,the European study of organic rich sedimentary rocks supported the biogenic theory (Schubert 1915) and followed by the USGS that oils originates from the organic rich shale (Arnold and Anderson 1907) . This theory came in lime light when Trebis found a link between chlorophylls in living organism and porphyrin pigments a type of nitrogen mainly originates from chlorophylls, in petroleum (Trebis 1934) .Later(hunt 2002) and (Durand 2003) make further developments to better correlation with sedimentary rocks and oils . The major developments came by (M R Mello and J M Moldowan 2005) when the used the high resolution geochemistry technology (HRGT) to show Oil samples related to sedimentary rocks of a certain depositional environment and geologic age show biomarkers derived from organisms that are known to have derived from biological precursor that evolved by that time. They showed the better correlation between the sedimentary source rocks and global commercial oils accumulations .Tang 2000 and Clayton 1991 also tried to show more detailed modeling data for stable isotopes . The biggest claim by the followers of biogenic theory is that this theory has suggested a most successful method to find new locations of commercial interesting hydrocarbons and most of the drillers are using this well tested successful method from decades. So association of sedimentary source rocks with commercial oils cannot be denied.

Abiotic Method— Bacterial Action on Non-biotic Sources

Deep in the crust or in the mantle of the earth, bacteria may make oil abiotically, that is from sources that were never alive. One suspect is archaea, a microorganism in a different kingdom than bacteria. Archaea are found growing in Yellowstone National Park hot springs at 100°C or at boiling. For food,

Archaea use hydrogen that has been leached by water out of igneous rocks such as basalt. Archaea combine the hydrogen with carbon dioxide to make methane (natural gas). Methane is the simplest hydrocarbon, a compound of carbon and hydrogen. Other microorganisms or natural processes may join methane molecules together to get a long chain hydrocarbons or oil

1. Hydrogen plus carbon dioxide with the help of archaea yield methane plus water.

   archaea

2. $H_2 + CO_2 \xrightarrow{\text{Archaea}} CH_4 + H_2O$

The probable chemical explanation of above equation is Statement 1 above is a chemical equation showing that the 2 compounds on the left combine to make the 2 compounds on the right. Equation 2 above is the same chemical equation using symbols or abbreviations instead of words. A chemist uses abbreviations for the elements. For example, 1 atom of carbon equals "C." The smallest part of the element carbon that still is carbon is one atom of carbon. The elements, from which all matter is composed, are made of 92 different naturally occurring atoms. Compounds are made of 2 or more different elements combined chemically. For example, a carbon dioxide molecule equals 1 carbon atom and 2 oxygen atoms or CO_2. A molecule is the smallest part of a compound that still is that compound. The formula for water is always H_2O because the smallest part of the compound water is a water molecule made up of 2 atoms of hydrogen and 1 atom of oxygen. To form compounds, elements give up their physical and chemical properties to become a compound with different properties. For example, hydrogen and oxygen gases, which are very reactive even explosive, react together to become a stable liquid compound which we call water.

Abiotic Method—Chemical Action

1. Producing Methane

Synthetic oil has been produced in the laboratory since 1923 by processes similar to the serpentinite process. This process is believed to be the method by which oil is made from rocks like olivine, miles deep within the crust or even in the mantel. Olivine is a very abundant igneous mineral and is always found with basalts, carbonates, metal catalysts and other rocks needed to supply factors for the serpentinite process. In this process, olivine is turned into the metamorphic rock serpentinite and the mineral magnetite. Metamorphosis is accomplished by adding water, carbon dioxide, and heat from the mantel or a heat vent. The carbon dioxide could be there from creation or be from carbonate rocks. Carbon dioxide dissolved in water becomes carbonic acid just like in soda pop. The water, carbonic acid, transition metal catalysts, and heat at around 500^{0}C change the olivine to serpentinite, magnetite, and methane.

Olivine + water + carbonic acid $\xrightarrow{\text{catalysts}}$ serpentinite + magnetite + methane

$$(Fe,Mg)2SiO_4 + H_2O + H_2CO_3 \xrightarrow[\text{serpentinite}]{500^0C} + Fe_3O_4 + CH_4 + H_2O$$

Serpentinite is so abundant in California that it has become the state rock. Normally, metamorphic rock is dense and harder than the parent rock, but serpentinite has so much water added that not only is the structure changed but the rock is 40% less dense or bigger.

Producing Complex Hydrocarbons

Methane can be upgraded to more complex hydrocarbons (hydrogen and carbon containing compounds) by joining methane together and taking out extra hydrogen atoms. Experiments in the laboratory show that methane compressed to 30 to 40 Kbar yields hydrocarbons having properties similar to petroleum. Also rocks like basalts that contain the mineral olivine is abundant in transition metal catalysts like iron, nickel and chromium that may aid in producing complex hydrocarbons. A catalyst speeds up a reaction or helps the reaction take place, but it usually does not take part in the reaction and get used up. Metamorphic magnetite is an iron containing magnetite mineral which is a major catalyst in the production of methane to ethane. Magnetite is changed to hematite which is also present in serpentines.

Methane + magnetite + water $\xrightarrow{\text{Heat}}$ ethane + hematite + carbonic acid

Compression

$$CH_4 + Fe_3O_4 + H_2O \qquad C_2H_6 + Fe_2O_3 + H_2CO_3$$

Notice that the 2 methanes have lost 2 hydrogens when they combine to make ethane. The hydrogens are picked up by a carbonate (CO3) and form carbonic acid. The extra acid speeds up the metamorphosis of olives to serpentine. The hot gaseous hydrocarbons migrate to the surface via gas pressure and the centripetal force from the earth rotating. The hydrocarbons condense to form liquid pools and are trapped beneath sedimentary rock close to the surface of the earth.

Abiogenic origin of petroleum*; *Additional evidences

This theory recognize that petroleum is primordial material of deep origin (Kutcherov, krayushikn 2010) . According to this theory hydrocarbons compounds generate in deep origin of earth and migrate throw the deep fault into the crust of the earth .Thus the accumulations of hydrocarbons is a natural process without any involvement of deceased biological material . According to Abyssal abiotic theory following conditions are necessary for the synthesis of hydrocarbons. 1) adequate high pressure and temperature .2) donor source of hydrogen and carbons. 3) a thermodynamically favorable reaction environment .

Polymerization of hydrocarbons take place in the temperature range 600-1500 degree C and the pressure range of 20-70 kbar (Kenny 2002) (e.g. under diamond anvil) . and these conditions prevail in the deep origin of the earth at depth level of 70-250 km (Carlson 2005) .

Gold recognized that the huge quantity of hydrocarbons is present in the massive outer planets and their satellites with huge amount of methane present in the extensive atmospheres of Saturn, Jupiter, Neptune. It is therefore logical no special mechanism for generation of hydrocarbons on earth only (Gold,1993) . NASA has also confirmed the huge hydrocarbons lakes and ocean of hydrocarbons on the surface of the Titan and thought to be abiotic origin without any involvement of biological debris . Some of the meteorite that falls on earth contains tar like hydrocarbons . comets such as Halley and Hale-Bopp are thought to have tar like skin covering with dirty snow ball. The common association of hydrocarbons with the inert gas helium is also taken a strong evidence of deep source of hydrocarbons (GOLD 1993). We have observed presence of some traces element like V, Ni,Cu,Co,Zn..etc in hydrocarbons which also do not clearly explain the biotic origin of petroleum (szatmariet al, 2005). According to the author of the paper ,they have analyzed 68 Brazilian oil and nine foreign oils and determined 24 metal traces in the oils showed fine correlation of the oils with CI chondrite and mantle peridotites, and worse correlation with oceanic and continental crust, and none with seawater. The high molecular weight sedimentary organic matter is termed kerogen from the Greek for "wax former." It is worth noting that not all of life's organic matter is reflected in kerogen. Even under relatively favorable conditions less that 1% of the starting organism, representing the most resistant chemical constituents, may be preserved (Demaison and Moore 1980). The Fischer-Tropsch synthesis (Fischer and Tropsch 1926) involves the conversion of carbon monoxide or carbon dioxide to hydrocarbons: The products of the Fischer-Tropsch synthesis are low molecular weight hydrocarbons and often form a Schulz-Flory distribution, where the log of the hydrocarbon concentration decreases linearly with increasing carbon numbers (Salvi and WilliamsJones 1997). The Fischer-Tropsch process has been proposed as a generator of hydrocarbons in hydrothermal vent settings (Horita and Berndt 1999; Foustoukos and Seyfried 2004; McCollom and Seewald 2006; Proskurowski et al.

2008; Proskurowski et al. 2008). Volcanoes bring out methane from deep in the earth.Under slightly different conditions, the metamorphosis of olivine can form talc- carbonate schists and magnesite stringer, Since these are present in serpentine rock, the methane producing process must also be active. There are others tons of strong and scientific evidences in favour of abiotic theory that also cannot be ignored. But there are few questions which are against the abiotic theory will arise. How can there be enough fine cracks in the rocks or pore space deep within the earth to allow for oil to be made abiotically and then to seep to the surface.

Much water is needed for the serpentine process and the subsequent joining of the methane molecules. Where does all this water come from deep within the crust that has supposedly produced all the inland, non-oceanic wells. There also is limited evidence that major serpentine belts underlie the continental sedimentary basins which hosts oil.

In conventional biogenic theory, oil buried too deep is turned into natural gas at temperatures between 120°C to 220°C. As one goes deeper, even natural gas would be destroyed by the higher temperatures above 220°C. This is the opposite of abiotic oil theory.

CONCLUSION :

Taking the strong evidences of both we have reached at conclusion that deep and abiotic sources had filled the earth oceans, lakes, pools and rivers with huge abiotic hydrocarbons in the past history of the earth, light hydrocarbons has been evaporated and remaining hydrocarbon bearing sludge has formed the productive sedimentary source rocks after mixing with ancient bio mass and these abiotic hydrocarbons has obtained some biotic characteristics in the burial history of the mixture to confuse us. Organic rich sedimentary rocks that has been formed without any involvement of these abiotic hydrocarbons are DRY and we are not getting any significant quantity of hydrocarbons for commercial use .So abiotic sources are the major contributor in the Global commercial hydrocarbons also . we also agreed that there is no need to change the earlier well tested method to find new locations of oils suggested by the fossil fuel theory but some more signatures can be added to make it more viable and to avoid dry holes. Hence a well-balanced theory is today's major requirement which will help future hydrocarbon exploration efficiently.

Acknowledgement

With the deep sense of gratitude I would like to thank SURESH BANSAL (Independent Researcher) for his support and guidance and give me the chance to take part in his project "True Origin Of Hydrocarbon". It is a matter of immense pleasure to work with him and I am really grateful to him for giving me permission to write this short note as a part of his project.

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পাথর ও আমি

তারক প্রধান

—অনুলিখন শুভম সরকার

আমার প্রেসিডেন্সিতে যোগদান করা ১৯৮৬ সালে, গাড়ি চালানোর সূত্র ধরে। তখন বিভাগীয় প্রধান ছিলেন ড. প্রদীপ কুমার গঙ্গোপাধ্যায় মহাশয়। প্রথম field-এ যাওয়া ওই বছরই, স্যারের সঙ্গো কাশ্মীরে। ড্রাইভার হওয়ার আগে আমি মেকানিক-এর কাজ করেছি। তাই যখন ঠিক হল যে field-এ একজন ড্রাইভার যাবে তখন আমাকেই select করা হল, যেহেতু আমি মেকানিক-এর কাজটাও জানি।

মজার কথা হল, সেই আমার প্রথম পাহাড় দেখা। field-এ গেলেও আমি গাড়িতে বসে থাকতাম না। স্যারেদের সঙ্গো সঙ্গো Exposure দেখতে চলে যেতাম। দেখতাম পাথরের মধ্যে কি সুন্দর fold দেখছেন, sample হাতে নিয়ে lense দিয়ে Grain দেখছেন। বেশ মজা লাগল। আমিও দেখতে শুরু করলাম স্যারদের সঙ্গো। সেই আমার Geology করার শুরু।

তারপর স্যার অবসর নিলেন, প্রফেসর গৌরীশঙ্কর ঘটক Head হলেন, আমি আস্তে আস্তে slide বানানোর দিকে ঝুঁকলাম। কিন্তু আমার প্রথম নিজের হাতে slide বানানো শুরু হয়েছিল 1998 সালে। তখন Department-এর Head হচ্ছেন ড. হরেন্দ্র নাথ ভট্টাচার্য্য। 86 থেকে 98 অবধি অনেকবার field-এ গেছি, পাথর চিনেছি, শক্ত পাথর, নরম পাথর হাতে নিয়ে চেনা, তাদের slide বানানোর জন্য ভিন্ন রকমের Treatement-এর প্রয়োজন বুঝেছি।

নিজে হাতে যখন slide বানানো শুরু করলাম তখন PDG sir (প্রফেসর প্রবীর দাশগুপ্ত) আমায় প্রচুর Help করলেন। আমার slide তৈরির বুদ্ধির সিংহভাগ PDG-র থেকে নেওয়া। যেমন আমাদের slide তৈরি মানে কাঁচের উপর প্রচুর ধকল যায়। আর তাই আগে হত কি Mount করার পর কাঁচ থেকে পাথরের বেশীরভাগই উঠে যেত। আমি তাই ঠিক করি,করার আগেই কাঁচটাকে একটু ঘসে নিতে হবে। তাতে আঁঠাটাও ধরবে ভাল। অনেকে বলেন যে, এতে নাকি আলো ঠিক ভাবে আসেনা। কিন্তু যখনই তাতে আঁঠা দেওয়া হচ্ছে তখনই তো পুরো কাঁচের Surface টা আবার smooth হয়ে যাচ্ছে। আর এই ভাবে slide তৈরি করতে শুরু করার পর থেকে slide থেকে পাথর উঠে আসাও অনেক কমে গেছে। বিভিন্ন সময়ে slide তৈরি করতে করতে আটকে গেছি, PDG sir-এর কাছে গেছি, sir রাস্তা দেখিয়েছেন।

এরপর আস্তে আস্তে Department-এর Sir-রা বিভিন্ন Seminar-এ গেছেন, সেখানে গিয়ে ওনাদের মুখে মুখে অন্যান্য Institute এমনকি বিদেশের লোকেরাও জেনেছেন। এভাবে বাইরের থেকে Slide-এর বরাত আসা শুরু।

তখনও মজা হয়েছে। বিদেশ থেকে লোক এসেছেন, তাকে গাড়িতে করে আমাকেই আনতে হয়েছে, আবার আমাকেই তাদের সঙ্গো Field-এও

যেতে হয়েছে। তার পাথর দিয়ে আমাকেই Slide বানিয়ে দিতে হয়েছে।

আগে আমাদের Slide ঘষতে হত হাতে ধরে, আমি Slide Holder বানালাম, ফলে - Mount করার পর যে Slide ভেঙ্গে যেত তার সম্ভাবনাও অনেক কমে গেল। এখন বাইরে অন্য জায়গায় হয়তো হোল্ডার ব্যবহার করে, যা হয়তো বাজারে কিনতে ও পাওয়া যায়। কিন্তু আমি Lab-এ যেগুলো ব্যবহার করি সব আমার নিজে হাতে বানানো।

যারা নতুন Slide বানাতে শিখছো, নিজেরা বানাবে ভাবছো - তাদের জন্য বলি, আগে পাথরটা চেনো, তার উপর নির্ভর করে তার Preparation করতে হবে, যদি soft rock হয়, তো Vaccum Chamber-এ আঠা (Araldite,এখন আর Canada Balsam ব্যবহার করা হয় না) দিয়ে cook করতে হবে। আর ভাল Slide তৈরি করার জন্য step by step পুরো ব্যাপারটাকে ভাল করে করতে হবে। মনে রাখতে হবে তাড়াহুরো করে ভাল Slide করা যাবেনা। একটা পাথর কত কোটি কোটি বছর ধরে তৈরি হয় তা আপনারা আমার থেকে ভালো জানেন, সেখান থেকে Slide তৈরি করতে গিয়ে যদি আর একটু বেশী সময় দেওয়া যায় তাহলে ভালই হবে।

Petrography and modal mineralogy of lamprophyre dykes of Barakar Formation, Raniganj Coalfield

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Introduction

The coal bearing Gondwana Group of rocks of the eastern Indian coalfields are intruded by innumerable dykes and sills of lamproitic and lamprophyric compositions. Such ultramafic-ultrapotassic (lamprophyres/ lamproites) are believed to have been emplaced during the early Cretaceous (<"105-115 Ma) period and associated with the Kerguelen hot-spot plume magmatism and may have genetic linkage to Rajmahal-Sylhet basalts, alkaline-carbonatite complexes and mafic dyke swarm of Shillong plateau. These intrusives intrude mostly the Barakar Formation as sub-vertical dykes or sub-horizontal sills trending E-W or ENE-WSW and at places display conspicuous thermal metamorphism by completely de-volatilising the coal seams. These intrusive rocks are considered to be members of a spectrum of modally-diverse peralkaline rocks, formed from a common parental magma produced by the partial melting of the ancient metasomatized lithospheric mantle of the north Singhbhum Craton.

Petrography

The present study is based on thin sections of lamprophyres, which intrude the sedimentary rocks of Barakar Formation. Detailed study of the slide indicates overall abundance of Phlogopite in the sample along with calcite, sphene and chloritised olivine as chief constituents. These minerals are accompanied by apatite, perovskite, feldspar, Iron oxides etc. which occur as accessory minerals.

The mineral Phlogopite, in general, shows very high refractive indices and in most cases, exhibits panidiomorphic granular texture i.e. dominanantly of euhedral grains. The mineral occurs both as phenocrysts and as a constituent of the groundmass. The later characteristically shows majority of elongated to acicular grains. Fracture is abundant both in phenocrysts and groundmass of phlogopite. Sometimes, fragments or phenocrysts(rarely)of other minerals such as calcite, sphene are also seen along with phlogopite phenocrysts. The groundmass of the rock contains extensive amount of calcite, although phenocrysts of calcite are also frequently noticed. Majority of euhedral grains are also evident in case of this mineral. Fractures are observed in significant numbers, both in phenocrysts and groundmass of calcite. Many of the calcite phenocrysts contain inclusions of other minerals, especially of opaque grains. In some cases, the mineral occurs as radiating crystal aggregates. Rounded or elongated crystals of chloritised olivine, characterised by greenish yellow body colour are also present both as phenocrysts and in groundmass. Inclusion of calcite grains are observed in many of the phenocrysts of chloritised olivine. The rock, in general, exhibits panidiomorphic granular texture and equigranular habit. Amount of sphene in the given sample-is also significant enough. It occurs both as phenocrysts as well as constituent of groundmass. Euhedral habit of majority grains of Sphene leads to panidiomorphic granular texture of the mineral. In some cases, the mineral forms clusters.Perovskite is found sometimes included within or in adjacent places of the calcite pheno-crysts. Sphene and calcite sometimes, exhibit poikilitic texture. The groundmass of the thin section, overall, is characteristically fine-grained.

Modal analysis

Modal analysis produces an accurate representation of distribution and volume percent of the minerals within a rock. Three methods of analysis are used:

1. Measure the surface area of mineral grains of the same mineral, relative to the total surface area of the thin section of rock.
2. Measure the intercepts of each mineral along a series of lines.
3. Point Count - Count each mineral occurrence along a series of traverse line across a given thin section. The modal analysis of lamprophyre has been carried out using point count method and the result is given below in tabular form-

Table: Modal analysis of the given thin section produces the result as follows:

MINERALS	***SLIDE NO. S-5***	***SLIDE NO. S-8***	***SLIDE NO. S-13***
Phlogopite phenocryst	3.4%	-	32.7%
Phlogopitegroundmass	19.1%	20.8%	8.4%
Calcite phenocryst	7.2%	7.7%	18.5%
Calcitegroundmass	29.8%	22.6%	15.0%
Sphene phenocryst	11.5%	-	-
Sphenegroundmass	15.5%	-	-
Iron oxide groundmass	13.5%	10.1%	5.2%
Chloritised Olivine phenocryst	-	19.0%	-
Chloritised Olivine groundmass	-	19.6%	-
Perovskite phenocryst	-	-	11.4%
Perovskite groundmass	-	-	8.7%

According IUGS scheme of classification the lamprophyres dykes of present study can be classified as mica lamprophyres and the result indicates high amount of MgO and CaO in the rock samples, which is compatible with the data produced by XRF analysis of the rock

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LINEATION

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Abstract

Linear structures are a common feature in rocks, which develop in different scales. Similarly its origin may be primary or secondary. Distinction of different lineations in the field is essential, and for this purpose a suitable classification scheme is necessary to be in hand. To avoid ambiguity between two different terms, description of linear structures should be based on morphology, rather than genesis. The systematic study of linear structures would of course unravel its genesis and relation with the other deformation structures through space and time.

Introduction

In outcrops often we observe linear structures. The linear structure is one in which one dimension is considerably longer than the other two. In 3D space it represents a vector having specific magnitude and direction of inclination. Of course, it develops on different scales. In other words, the magnitude or intensity of a linear structure may vary from one location to the other. Thus the systematic study of the linear structures would obviously provide important clues to the geological phenomena. Such study, of course, needs a suitable classification in hand, in order to distinguish different linear structures in the field.One of the drawbacks of the existing nomenclature of the linear structures, rather to say lineation, is association of terms indicating genesis, e.g., 'stretching' lineation, with morphology-based names, e.g., 'mineral' lineation. Hence on the basis of essentially morphology Piazolo and Passchier (2002) have redefined the commonly used lineations and proposed a more practical scheme of classification to be useful in the field. However, on the basis of scale, mode of origin, properties of the defining objects and type of host material the linear structures can be classified under different possible schemes. An attempt to combine all these classification schemes under a generalized one has been made in this article.

Scale of linear structure

The geological features may develop on micro- through hand specimen and outcrop to regional or even global scales, though an individual feature does not necessarily develop over all these scales. Based on the scale of development the linear structures can be divided into two types - those which develop on micro- to regional scale are lineations and the features, developed on global scale, are lineaments, e.g., mid-ocean ridge, mountain belt, master joint etc. (Fig. 1). In the following sections classification of the lineations will be dealt in.

Origin of linear structure

The lineation, i.e., linear fabric in rocks may be primary in origin, for example, parting lineation and flute cast in sandstone, and flow lineation in ropy lava, or secondary, i.e., tectonic in origin, for example, mineral lineation, intersection lineation etc.

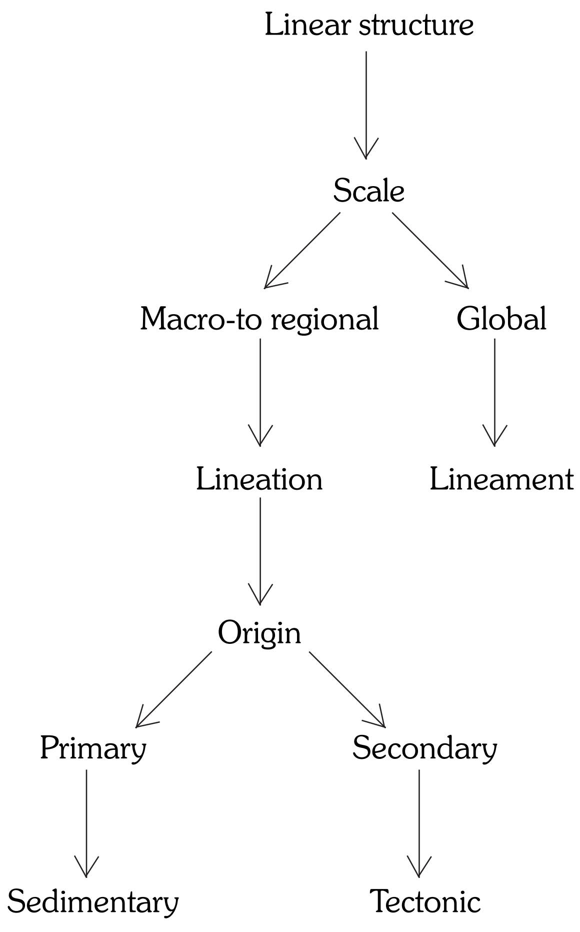


Fig. 1. Classification of lineags structures on the basis of scale.

(Fig. 1). It is noteworthy that the secondary linear fabric is generally termed as lineation, as the planar fabric, secondary in origin, is referred to as foliation. Both the primary and secondary linear fabrics develop on micro- through hand specimen and outcrop to regional scale. The two linear fabrics can be identified in the field by a student of geology, having knowledge of basic principles and ideas of petrology, the distinguishing characters of which can be mentioned as below (Table 1).

Table 1: Distinguishing characters of primary and secondary fabrics

Primary linear fabric	***Secondary linear fabric***
Always develop on a planar fabric like bedding surface	Either restricted to a surface or may develop individually even in absence of any planar fabric
Often associated with other primary structures	Usually not associated with any primary structures, except bedding surface
Orientation is usually variable, mean is parallel to the direction of flow of the depositing medium or of lava	Orientation is usually persistent, mean being perpendicular to the tectonic force direction
Not associated with foliation	Associated with foliation, except in L-tectonite
Never parallel to fold hinge line	Often parallel to the fold hinge line, except in case of foliation transected fold
Develops on hand specimen to outcrop scale	Develops on micro- to regional scale

The following sections will cover solely classification of secondary linear fabrics, i.e., lineation (tectonic), a relatively infrequent but not least important tool, useful to unravel deformation history of a region.

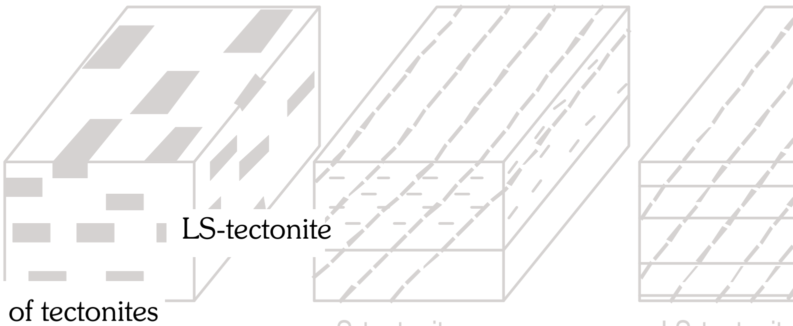
Objects defining lineation

The term lineation describes any linear feature which occurs penetratively in a rock. Nowadays, four main types of lineations are generally distinguished (Ramsay, 1967; Hobbs et al., 1976; Twiss and Moores, 1992; Passchier and Trouw, 1996). *Mineral lineation* is defined by the preferred (i.e., statistically similar) orientation of single undeformed mineral grains with an elongate or platy habit, whereas *Stretching lineation* is defined either by: (a) prolate aggregates of equidimensional or slightly elongate grains, or (b) prolate deformed single grains of minerals such as quartz, calcite, feldspar, which normally have an equidimensional shape when undeformed.The hinge lines (or zones) of microfolds and/or kink bands in the foliation planes constitute *Crenulation lineation*.On the other hand, the lines of intersection between two sets of surfaces represent *Intersection*

Such a lineation did not develop due to stretching into an ellipsoidal shape. Further the degree of penetrativeness needs to be taken into account during lineation study and naming of the lineation bearing deformed rocks accordingly.

Penetrativeness and tectonite

The ***penetrative lineation*** is in general build up as a linear fabric produced due to preferred alignment of elongate mineral grains, even in a non-foliated rock body. For example, mineral lineation in a massive granite body, if subhorizontal, it indicates



L-tectonite S-tectonite LS-tectonite

Fig. 2 Different types of tectonites

Fig. 2 Different types of tectonites

lineation. This existing system of terminology has a number of problems. For example, it is difficult to distinguish the type (b) stretching lineation from a mineral lineation. Similarly, if a polycrystalline layer in a mylonite is dismembered by shear bands, the result may be a ‘stretching’ lineation at right angles to the orientation of the bulk finite strain axis.

emplacement as a thrust sheet, otherwise if steep, it indicates vertical uplift of the crystallizing magma body. Such a deformed rock comprising lineation as the dominant fabric is referred to as ***L-tectonite*** (Fig. 2).

Surface lineation is restricted to a surface. If the surface is a slip plane of brittle deformation (slickenside), the lineation is not penetrative and is called

slickenline(or slickenside lineation). Of course, brittle deformation usually takes place covering a considerably thick zone, where slickenline may appear as a penetrative element. However, on an individual slip plane it occurs as a surface feature. If, on the other hand, the deformation is plastic and both the lineation and foliation (S-fabric) keep balance in penetrativeness, then such deformed rock is called ***LS-tectonite*** (Fig. 2).

It is worth to mention here that if the deformed foliated rock lacks in linear fabric, then it is called ***S-tectonite*** (Fig. 2).

Definition and classification of lineation

Penetrative lineation

As mentioned above the common lineation (tectonic) types are mineral, stretching, intersection and crenulation lineations. The terms have been redefined by Piazolo and Passchier (2004) in order to classify them solely on the basis of morphology. They introduced two new general terms, object lineation and trace lineation. The former is one which is defined by parallel arrangement of distinct elongate parts of the rock with a measurable volume (Fig. 3). The trace lineation, on the other hand, is represented by lines of intersection of surfaces or by hinge lines of crenulations. Thus it represents material lines of zero volume. Object lineations are further divided into grain and aggregate lineations. According to these authors, a grain lineation consists of prolate single grains of a mineral whereby the long axes of the mineral grains are similarly oriented. Moreover a grain lineation may have elements from both stretching and mineral lineations. Thus the use of the term, grain lineation, eliminates the ambiguity between stretching and mineral lineations (Piazolo and Passchier, 2002). However, if the crystal habits of the minerals and, secondly, the consideration of whether the mineral grains are inherently elongate or elongated due to deformation are taken into account, then the mineral and stretching lineations would be distinguishable without ambiguity (Fig. 3). Thus the mineral and stretching lineations are defined as the two types of grain lineations, marked by statistically preferred alignment of elongate and elongated mineral grains respectively.

Similarly an aggregate lineation is defined by prolate aggregates of grains of the same or several different minerals in which individual grains have a smaller aspect ratio than the overall aggregate (Piazolo and Passchier, 2002). However, like grain lineation the aggregate lineation can further be divided into two types. Based on mineral type (single or multiple) an aggregate lineation may be monomineral or polymineral lineation (Fig. 3). Monomineral lineation can be divided into two, porphyroclastic lineation and porphyroblastic lineation (Fig. 3). The porphyroclastic lineation is defined by parallel arrangement of elongate porphyroclasts, preserving relict old grains, whereas in case of the latter the elongate porphyroblasts comprise new mineral grains. On the other hand, the polymineral lineation may be defined

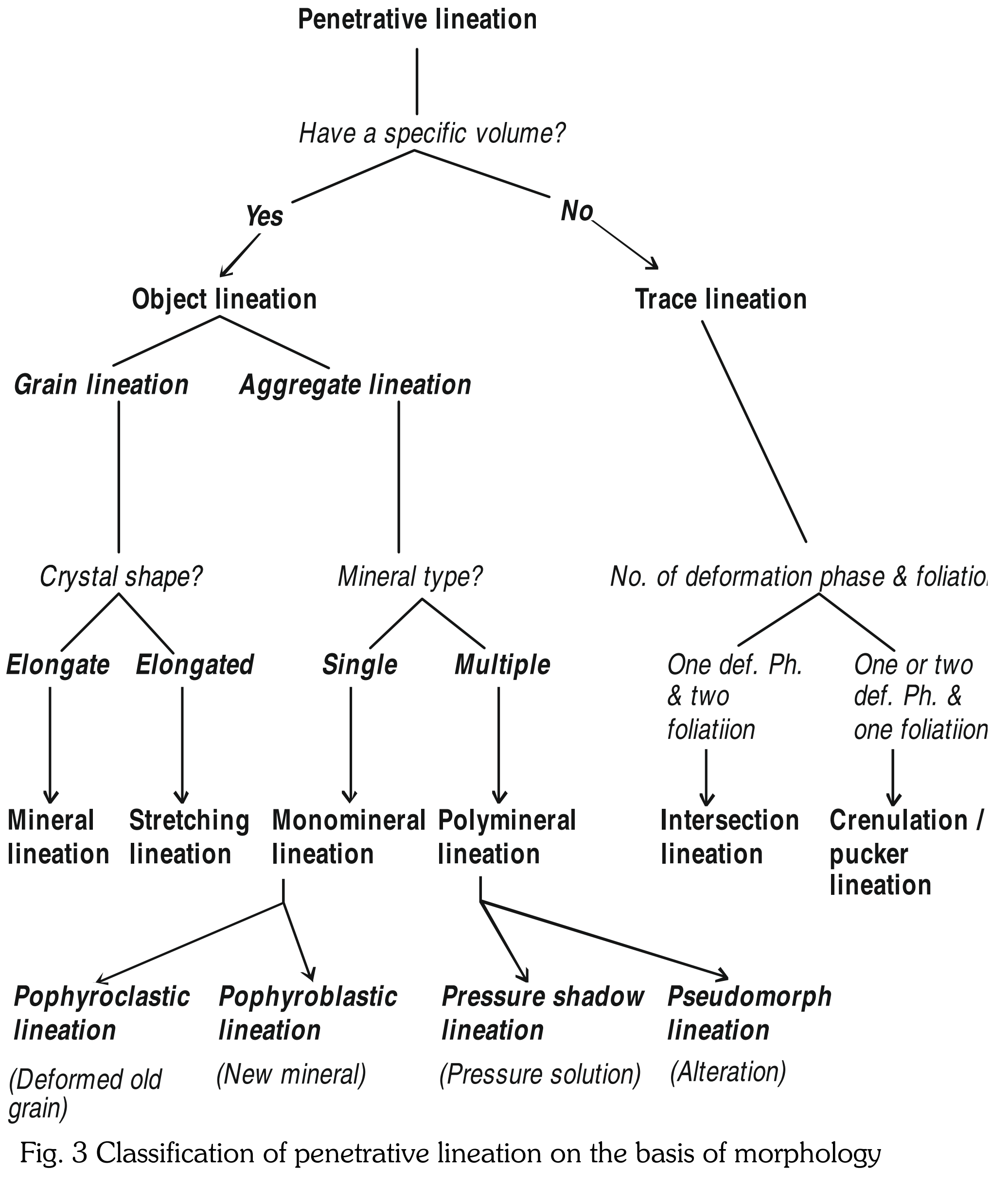


Fig. 3 Classification of penetrative lineation on the basis of morphology

by parallel elongate pressure solution, beard structure or even pseudomorph of alteration products. Therefore such aggregate lineations may be termed as pressure shadow and psedomorph lineation (Fig. 3).

Trace lineation with zero volume includes two genetically distinct lineation types. The term intersection lineation itself stands for generation by intersection between two surfaces whereby the crenulation lineation is formed by microfolding of a surface (Fig. 3). Thus the development of the former needs at least two surfaces, whereas that of the latter takes place on a surface.

Non-penetrative lineation

The non-penetrative lineations that develop within a single surface, on the basis of deformation regime,can be divided into two types. The lineations which form in brittle deformation regime, i.e., in relation to fault movement are called slickenline or slickside lineations. On the other hand, the lineations which form in ductile deformation regime, i.e., in relation to folding are known as mullion (corrugation on fold surface) (Fig. 4). Slickenlines can be further classified into two types, depending upon whether there any solute present along the movement surface (fault surface) or not. In absence of any fluid slickenlines are developed as striations on the polished slickenside surfaces,

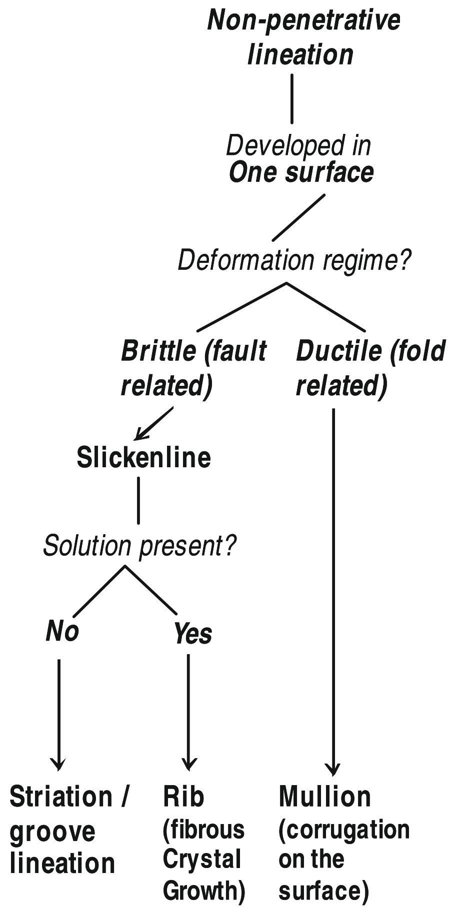


Fig. 4 Classification of non-penetrative lineation

whereas in presence of the same rib structures are developed (Fig. 4).

Application of lineation

Early descriptions of linear structures categorized lineations according to their orientation with respect to fold geometry, whereby a-lineations are perpendicular and b-lineations parallel to the fold axis (Sander, 1930). Such geometric constraints are not applicable in case of all types of lineations. In general trace lineations including crenulation and intersection lineations may represent b-lineation, provided a single phase of buckle folding with axial planar foliation development takes place. On the other hand object lineations would represent a-lineation. Later on stretching and mineral lineations have generally been regarded as reliable tool to determine tectonic transport direction and to decipher the superposition of deformation events in rocks (Ramsay, 1958; Shackleton, 1993).

The presence and strength of a lineation in a deformed rock is not only a function of finite strain but is also strongly influenced by other factors like (i) the initial rock fabric and mineral composition and (ii) the ratio of initial grain size to dynamically recrystallized grain size. These factors determine how processes active during and after deformation will affect the development of a lineation, the object lineation in particular.

Conclusions

Description of linear structures should be based on morphology, rather than genesis. The systematic study of linear structures would of course unravel its genesis and relation with the other deformation structures through space and time. In order to carry out such systematic study it is necessary to determine the strength of lineation, which is a statistical parameter defining consistency in orientation. However in the outcrops of superposed deformation, care should be taken to assess the strength of lineation. Because a lineation developed in early phase of deformation may be affected by the later phase of deformation, and lose the consistency in orientation, i.e., strength.

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