# International Symposium
# On
# CARBON MANAGEMENT & CLIMATE CHANGE AND ROLE OF APPLIED GEOCHEMISTRY IN MINERAL EXPLORATION

25-27 November 2009

# ABSTRACTS

*Knowledge & Technology Partner*

**Oil & Natural Gas Corpotation Limited (ONGC)**

**National Geophysical Research Institute (NGRI)**
**Indian Society of Applied Geochemists (ISAG)**
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# CURTAIN RAISER

It was in 1824 that a French Physicist, Joseph Fourier was the first to use Greenhouse analogy to describe the importance of atmosphere in trapping heat and influencing Earth's temperature. Svante Arhenius (1896) suggested that human activity produces greenhouse gases. British engineer Guy Callender proved that fossil fuel burning is responsible for warming of world climate. The first World Climate conference (1979) urged governments to foresee and prevent potential man-made changes to climate. Kyoto protocol (1997) set binding targets for industrialised nations to reduce emissions by five percent by 2012. But in 2001 the US president removed his country from the Kyoto process.

The receding of glaciers, breaking off of Larsen B Ice Shelf from Antarctica, rapid melting of Arctic sea-ice habitat of polar bear are danger signs indicating possibilities of sea level rise and related devastations. Global economic crisis, however has led to fall of carbon emissions by three percent.

There has been thirty percent increase in atmospheric concentrations of carbon dioxide since the industrial of 1860. In this context the role of oceans in transferring carbon dioxide from the surface to the deep sea becomes significant. The importance of biogeochemistry, lipid chemistry of geologically significant microbes and microbially dominant ecosystems have to be properly understood. Organic and isotopic indicators of climate change, biotic evolution, mass extinction, biomarkers in sediments and petroleum, biogeochemical fossils are current active fields of research. In this symposium we are going to have the presentation of a number of excellent papers and keynote addresses on these topics, which are likely to generate lively discussions and come out with valuable suggestions.

The second part of the symposium pertains to the application of geochemistry in mineral exploration. There are well researched papers on the use of critical element ratios in rock evaluation and mineral exploration. Noble metal and uranium exploration and the application of genetic geochemical models in exploration technologies are the subject matter of many papers. Role of indicator elements and minerals in exploration technology will be discussed. Major advances in applied mineral exploration research have allowed researchers to quantify models for all types of deposits.

The presentations in this symposium will throw lights on new geochemical technologies and tools and highlight new strategies for mineral exploration of concealed deposits. Advances in multi elemental analysis of fluid and solid micro-crystalline inclusions by absolute PIXE and related techniques will be presented.

Greater use of Uranium for power production will reduce carbon dioxide emissions and help governments to maintain growth with minimum degradation of environment and thus help indirectly in climatic control. The proposed United Nation summit at Copenhagen in December 2009 will hopefully negotiate a new climate change treaty in the interest of mankind. It will thus be ideal for the geoscientists present at this symposium to take the matter seriously and suggest roles for our community to help make the world a safer place for posterity.

Date: 25-11-2009

K.K.Dwivedy
President, ISAG

# ISAG, 1997-2009

The Indian Society of Applied Geochemists (ISAG) has successfully completed a decade of eventful functioning. The ISAG has been registered during 1997 with the Registrar of Societies, Government of Andhra Pradesh, India. On behalf of Executive Council (EC) I can confidently share my happiness that the Society maintained its academic credibility since 1997. This is mostly due to the cooperation of EC and also due to the continuation in the office of some founder members of the Society in the EC.

The EC, especially Dr. K. K. Dwivedy, the President of the Society, has been extending fullest possible support to the activities of ISAG and without which it would have been impossible to develop the Society.

During these twelve years, the Society crossed several hurdles. Each year, it tried step-by-step to improve and implement the enshrined aims and objectives of the constitution. The most important milestone was the starting of publication of Journal of Applied Geochemistry (JAG). The first issue was released in January 1999 during the inauguration of National symposium on ‘Applied Geochemistry -Retrospect and Prospect’ by Sri V. Ananda Rao, IAS the then Chief Secretary, Govt. of Andhra Pradesh. Since then, nine (9) volumes covering eighteen (18) issues, excluding ‘special volumes’, of the journal have been published uninterruptedly and released on time, till today. Another important milestone is that the Journal has been accepted and well received by the earth scientists both nationally and internationally. It is also well subscribed by fellows, institutions, and others.

The EC of ISAG pursued vibrant academic activities of contemporary relevance with a human touch in each attempt so far. Successful organization of three international symposia and three national symposia on various aspects of applied geochemistry, in a geologically-short period of over a decade is a marking testimony to the impressive and fruitful functioning of the Society.

The first international symposium(1991)  was on ‘Applied Geochemistry’, the second national symposium (1999) on ‘Applied Geochemistry-Retrospect and Prospect’ and simultaneous release of *the first issue* of *Journal of Applied Geochemistry*, the third international symposium (2001) was on ‘Applied Geochemistry in the Coming Decades’, the fourth national symposium (2003) on ‘Applied Geochemistry in Exploration for Minerals and Oil’ and the fifth international symposium (2005) on ‘Applied Geochemistry in the Evaluation of Onshore and Offshore Geo-Resources’, the sixth national symposium (2007) on ‘Applied Geochemistry of Energy resources and Precious metals’ and the seventh international symposium (2009) on ‘Carbon Management & Climate Change and Role of Applied Geochemistry in Mineral Exploration’.

Initially, the society took up multiple fields of applied geochemistry for each event but many of our well wishers and fellows wished the society pay attention on focused subjects also. The society has taken up the most important theme of the Planet Earth focused on Carbon management & climate change and also included Role of Applied Geochemistry in mineral exploration to continue the efforts of ISAG, to keep the earth scientists abreast with latest techniques. The response of the earth scientists for the scheduled event so far has been very satisfying.

These seven symposia covered various fields including gold and tungsten mineralization, new trends in exploration geochemistry and data processing, fluorosis and hydro-geochemistry, environmental geochemistry/ geochemical engineering, energy resources, water resources, magmatisam, metallogeny, sedimentary-ore geochemistry, exploration of metals and non-metals, integrated geological and geochemical studies, remote sensing and GIS in mineral exploration, precious metals (PGE, gold and diamond), radioactive minerals, marine mineral resources, oil & gas, ferrous and non-ferrous metals and industrial minerals, gas hydrates, coal & coal bed methane (CBM) and many more.

The proceedings of the symposia held so far have been released, as *special volumes* of the Journal of Applied geochemistry within a year after each symposium and circulated among fellows of the Society and complimentary copies to the important national and international earth scientists. The society received good response for the special volumes from many other individuals. These volumes have been reviewed by experts for journals in good standing, with positive comments on the quality of contents.

During the decade, the society undertook several additional important academic activities for the benefit of research scholars, scientists and professionals by organizing regularly many invited talks by experts and annual lectures by specialists. Eminent earth scientists from national earth science organizations participated in the events and delivered useful talks. A highlight of these programmes has been the special one-day workshop on “India-Sri Lanka Road Link -Lifting of Adam’s Bridge (Varadhi)” organised on 17 June 2005. Prof R. D. Schuiling of Utrecht University, an expert on geochemical engineering delivered the Keynote Lecture. National organisations in India such as AMD, GSI, NGRI, NMDC, ONGC etc deputed their scientists to the workshop.

The Society initially organized the AGM events in Hyderabad, its headquarters but later the events have bein organized at different parts of the nation, on invitation. The first annual general body meeting (AGM) was organized at NIO, Goa (2005), the second at WIHG at Dehradun (2006) and the third at GSI(WR), Jaipur (2007), the fourth at Madras University, Chennai (2008), fifth at Mysore University, Mysore (2009) and sixth next is scheduled at Pondicherry University, Port Blair, Andaman (2010). The two day AGM’s consist of one day workshop on Applied Geochemistry, a day of scientific discussions. Eminent earth scientists deliver lectures by invitation on a single topic like Oil and Gas, Himalayas, Oceans, Energy, Environment etc. The lectures were published regularly in the immediate issue of the Journal. The second day, the AGM with an invited talk by the Chief Guest.

The Society has also provided part finances for the young scientists as travel grant to those, whose article has been approved for presentation in the international symposia, seminars, workshops, etc. in fulfillment of one of the most important aims of the society. The society is also encouraging the young scientists in their research activities by providing expert advice, part finances for their work thus helping them to complete their Ph.Ds.

The society instituted four medals to be awarded annually during AGM for the best paper published in the journal, analytical geochemistry, mineral exploration by geochemical methods and nuclear energy; again fulfilling one of the main objectives of the society. The society continues to work hard to further strengthen its academic activities as long as there is solid support and encouragement extended by the fellows, scientists, professionals, etc. The EC is sure to receive similar support in future also.

Date: 25-11-2009

K. Surya Prakash Rao
Secretary

# Contents

# SESSION - I

# CARBON SEQUESTRATION AND MANAGEMENT

## CLIMATE CHANGE AND GLOBAL WARMING- FUTURE CHALLENGES AND ROLE OF DEVELOPING ECONOMIES

A.K. Balyan
*Oil and Natural Gas Corporation Ltd., New Delhi*

## CARBON SEQUESTRATION-STRATEGIES ADOPTED BY ONGC

A.K. Balyan
*Oil and Natural Gas Corporation Ltd., New Delhi*

## POLYMERISATION THEORY (THE CATALYTIC FORMATION OF OIL FROM $CO_2$ AND $CH_4$): APPLICATION OF AN ACCELERATED GEOLOGICAL PROCESS TO REMOVE CARBON OXIDES FROM FLUE GASES AND USE CARBON OXIDE SEQUESTRATION TO PRODUCE OIL IN SEDIMENTARY SEQUENCES

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Polymerisation theory has been used (Antia, 2009) to develop a two stage model of oil formation to explain the Zagros (and Persian Gulf) oil and gas accumulations (Iran). During Stage A: Vertically migrating $CH_4$, $SO_2$, CO, $CO_2$ and $H_2$ are captured and polymerised in a deep (>6000 m) hot (<300 - >450$^{o}$ C) pressured (<80 - >150 MPa) clay (or evaporite) self-sealing pressure mound to produce a methane gas containing a light oil/condensate ($C_1$ to $C_{14}$), $CO_2$, $H_2$, and $H_2S$. During Stage B: The hot (<300 - >450$^{o}$ C), high pressure (<80 - >300 MPa) gas/condensate is episodically discharged through vertical fracture zones, faults and vertical chimneys. The migrating super-critical fluids are trapped in a recipient shallow reservoir with a temperature of <30 - >170$^{o}$ C and a pressure of <9 to >40 MPa. The interaction of pore water chemistry in the host aquifer, and the temperature and pressure drop associated with the migrating super-critical gases, induces the formation of reduced iron. This reduced Fe catalyses the polymerisation of $C_{12}$ to $C_{50}$ alkanes, cycloalkanes and aromatics.

Analysis of low temperature (50 – 100$^{o}$ C) non-catalytic thermogenic oil formation from biomass, and catalytic alkane formation in low temperature (<10 - >20$^{o}$ C) medium pressure (9 – 12 MPa) gas pressure mounds associated with hydrates (offshore USA) have demonstrated that Stage A comprises two sequential groups of reaction. Stage A1 is a condensation reaction of the form $aCO_x + bCH_4 + cCH_xO + dCH_xO_2 + eH_2 = fC_2H_x + gC_2H_xO + hC_2H_xO_2$. Stage A2 is a dehydration, hydrogenation and polymerisation reaction of the form $aCO_x + bCH_4 + cCH_xO + dCH_xO_2 + eH_2 + fC_2H_x + gC_2H_xO + hC_2H_xO_2 = iC_zH_w + jH_2 + kH_2O$. In the geological environment, the rate constant for A2 is higher than the rate constant for A1.

Flue gases from fossil fuel combustion processes contain CO + $CO_2$ (<1% to >60%), nitrogen (<30% to >80%), $NO_x$, $SO_x$, S, Cl, F, $H_2$, $H_2S$, $C_xH_y$, $C_xH_yO_z$, $C_xH_yN_z$, particulates, ash, $O_2$, $H_2O$, and other chemicals. This gas composition is similar (if the $N_2$ content is ignored) to the composition of feed gas (produced by the thermal decomposition of organic matter) entering a geological pressure mound (Stage A).

Catalyst and reactor technology can be used to accelerate this geological process (Stage A1 and A2). This acceleration allows the direct capture of carbon oxides from untreated flue gases (associated with the combustion, or carbonisation of fossil fuels) by transforming them to products ($C_xH_y + C_xH_yO_z$) using routes A1 and A2. These products are not controlled substances under either the Kyoto or Montreal Protocols.

This process reduces the global warming potential of the residual flue gas emissions by removing both $CO_x$ and $CH_4$. The products ($C_xH_y$ + $C_xH_yO_z$) have value and can either be extracted from the product gas, or discharged directly into the environment.

Carbon sequestration involves the subterranean injection of $CO_x$ extracted from flue gases or the subterranean injection of the entire flue gas. This sequestration process can be used to mimic Stage B. The geological studies (Antia, 2009) have established that if (i) a hydrocarbon structural skeleton (of the form $C_xH_y$ or $C_xH_yO_z$) is present in the recipient reservoir (or injected gas), (ii) the injection process is associated with a substantial pressure drop between the injection source (e.g. borehole) and reservoir and, (iii) one or more injected fluids are super-critical fluids, then the general reaction (Stage B) $aCO_x + bCH_4 + cCH_xO + dCH_xO_2 + eH_2 + fC_2H_x + gC_2H_xO + hC_2H_xO_2 = iC_zH_w + jH_2 + kH_2O$ will occur. The process can be artificially accelerated by adjusting the pore water chemistry of the recipient oil (or gas) reservoir, or depleted oil (or gas) reservoir, or methane gas rich shale (self-sealing trap), or methane rich carbonaceous sediments, or methane gas rich turbidite sequence (which may be associated with hydrates). Modelling demonstrates that this sequestration strategy can result, over a 5 to 100 year period, in the conversion to oil of the majority of the injected $CO_2$. Injecting flue gas (containing nitrogen) results in the formation of a high purity nitrogen gas cap (95 - >99% purity). This high purity nitrogen gas may form an exploitable, important and valuable resource.

This analysis indicates that carbon oxides are an important resource, which if correctly managed (during capture and sequestration) will provide an important, valuable, and sustainable source of hydrocarbons, fuel, plastics, textiles, and chemicals. Future development is focused on (i) reducing the size and cost of the carbon capture plant, (ii) accelerating the conversion of the sequestered carbon dioxide (within the reservoir) to oil, and (iii) integrating the process of carbon ($CO_2$) capture and sequestration, followed by $CO_2$ conversion into transport fuels (naphtha, kerosene, aviation fuel, high cetane (60 – 110) gas-oil) into a simple, compact, low cost process.

### Reference

Antia, D.D.J., (2009). Polymerisation Theory – Formation of hydrocarbons in sedimentary strata (hydrates, clays, sandstones, carbonates, evaporites, volcanoclastics) from $CH_4$ and $CO_2$: Part I: Polymerisation concepts, kinetics, sources of hydrogen, and redox environment: Part II: Formation and Interpretation of Stage 1 to Stage 5 Oils: Part III: Hydrocarbon expulsion from the hydrodynamic flow regimes contained within a generating pressure mound: Part IV: Polymerisation modelling of sequestered carbon dioxide and waste organic liquids to hydrocarbons. Indian Journal of Petroleum Geology (accepted for publication 26/3/09).

## COMPARATIVE STUDIES ON GEOLOGICAL DISPOSAL OF NUCLEAR WASTES AND $CO_2$ SEQUESTRATION IN INDIA

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International Atomic Energy Agency (IAEA) has initiated a new Coordinated Research Programme (CRP) on techno economical comparisions of ultimate disposal facilities for nuclear wastes and $CO_2$. India is a prominent member in this group with Australia, Republic of Korea, Switzerland, Bulgaria, Chek Republic and Cuba as other participants. The project aims to focus on working out similarities and differences in these two concepts in terms of host rock, geological set up, excavation and construction technology, safety requirements, costing and environmental impact issues. This paper brings out preliminary comparative studies carried out in India under this project.

The geological disposal of nuclear waste and sequestration of $CO_2$ in geological formations fundamentally rely of capacity on suitable rocks in confining and isolating these wastes over extended periods of time. As both intend to exploit the proven ability of underground strata in achieving this objective, there appears remarkable similarities in these two approaches.

In India, the ultimate nuclear waste disposal facility is under consideration in granitic rocks in the depth range of about 400-500m in regions forming part of seismic zone I and II. The preferable locations are further expected to lie in regions with minimum rainfall, very low surface and groundwater potential without appreciable forest and mineral resources. The granitic rocks constituting about 20% of the total area of the country offer wide choice for such sites. On the contrary, the geological set ups for $CO_2$ sequestration under consideration worldwide including India, are depleted oil fields, saline aquifers and in some cases basaltic rocks. The construction of a nuclear waste disposal facility is challenging task as it requires highly controlled excavation and blasting methods to ensure minimum damage to host rock with a view to avoid creation of additional groundwater pathways around the facility. Such facilities are being planned to host about 10000 waste filled steel canisters initially with a provision to double its capacity. The geological sequestration of $CO_2$ is essentially an injection methodology that intends to utilize effective porosity of sedimentary units at greater depth. However, there are few cases where capability of some minerals to combine with $CO_2$ to form carbonates especially in basaltic rock. Basaltic rock constitutes an important host rock for nuclear waste disposal as well. Safety periods in the case of nuclear waste runs into tens of thousands of years due to very long half lives of radioisotopes of few elements like uranium, plutonium, iodine and technetium. The safety periods in the case of $CO_2$ appears to be of lower magnitude. The main mechanism leading to release of nuclear waste to environment is through their dissolution by groundwater and transport to accessible environment. The $CO_2$ disposal facility, whereas, will not be prone to such release. Nevertheless acidification groundwater is reported as a matter of safety concern.

Safety assessment in the case of nuclear waste disposal mainly focuses on estimation of radiological doses to member of public in distant future in the event of release of disposed waste to environment. The other safety indicator like concentration of radionuclide in various compartment of a disposal facility and radionuclide flux across compartments are also under consideration. The safety indicators reflecting protection against release of $CO_2$ from disposal site and its impact on human and environment are still evolving.

Transportation technology for nuclear waste through inland routes to a single disposal site is well established in India using specifically designed casks. However in the case of $CO_2$, due to very scattered locations of sources, the transport will mainly be pipe line based and at times may involve multiple injection sites. These safety requirements and cost of these two technologies are incomparable.

Emplacement technology in the case of nuclear waste mainly involve storage at surface, shipment to underground, emplacement in disposal pit, erection of clay barriers and closure of pit . These activities due to high radioactivity associated with such waste would require highly sophisticated remote handling systems and compactors. The injection technology, in the case of $CO_{2,}$ on the other hand would involve high pressure injections. As regards to social and ethical issues, the both approaches draw similar adverse public opinions and commands low acceptability worldwide. This is reflected in opposition to proposed nuclear waste disposal sites in USA, France, UK, Germany etc.

Thus, lot of progress has been made in India as regards to geological disposal of nuclear wastes including mockup experiments in underground mines. However studies on geological sequestration of $CO_2$ are still in their nascent stages and need to accelerate.

# EX-SITU MINERAL CARBONATION: A MODEL TO ASSESS THE $CO_2$ SEQUESTRATION POTENTIAL OF ULTRAMAFIC COMPLEXES IN INDIA

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India has favorable geology and excellent exploration potential by hosting the raw materials suitable for on site $CO_2$ mineral carbonation/mineral trapping, one of the sequestration methods considered for lowering greenhouse gas levels. There are numerous well studied layered ultramafic-mafic complexes rich in Mg bearing-silicates. Dunite and Peridotite rich zones constituting the major proportion of these complexes are currently considered as the most promising source of raw materials for ex-situ mineral carbonation process, since they contain the most magnesium by weight percentage, the component necessary for binding $CO_2$ to form the stable magnesium carbonate-Magnesite. Overburden/host rock mine waste containing peridotite, serpentine/serpentinite and pyroxenite stockpiled after the extraction of chromite-rich zones in present day mines operating in layered ultramafic complexes, provide a readily available source of the starting material required for on site sequestration of $CO_2$. India's well known layered ultramafic complexes have been studied extensively by earlier workers, for assessing their potential as possible hosts for base metals, chromium, nickel and PGE. The Sukinda Layered Ultramafic Complex and the Baula Nuasahi Layered Ultramafic Complex in Orissa and the Sitampundi Layered Ultramafic Complex in Tamil Nadu have been selected for this study, on the basis of existing data on mineralogy, geochemistry, the potential size of the resource and their accessibility and proximity to major $CO_2$ point sources of emission. This study drawing relevant information from current $CO_2$ research utilizes the above database to evaluate the mineral carbonation potential of the layered ultramafic province(s) and proposes a model feasible for on site ex-situ mineral carbonation.

# INDIA'S FOSSIL FUEL ENERGY SCENARIO AND CARBON MANAGEMENT

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India's fossil fuel energy scenario is mostly driven by coal, oil and gas and in the future unconventional sources of fuels such as oil shale, coal bed methane, gas hydrates, shale and tight gas and coal liquefaction may play an important role in the energy outlook. Coal remains and shall remain the most abundant and important fossil fuel in India, followed by oil and gas. The fossil fuel based thermal power stations are the largest point sources of $CO_2$ emission, which is a green house gas and is the major cause of environmental change.

Carbon management is a new world wide R and D initiative for capture and storage of $CO_2$ to mitigate global climate changes and is one of the greatest environmental challenges the world community is facing. The capture of $CO_2$ from point sources and storing it in the geological formations such as depleted hydrocarbon reservoirs for oil/gas recovery; coal beds; deep saline aquifers and basalt formations are the most viable options. The R and D plans in India towards $CO_2$ abatement for sustainable energy future will be presented and discussed. An overview of world energy scenario and India's outlook for unconventional sources of fossil fuel will also be presented.

# SESSION - II

# CARBON SEQUESTRATION AND MANAGEMENT (CONTINUED)

# NATIONAL PROGRAM ON CARBON CYCLE STUDIES FOR INDIA

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A detailed study of geochemical fate of carbon in various spheres of the Earth has attained very great importance in relation to green house gas effect of carbon dioxide and various aspects of global climate change. The current estimates of distribution of carbon distribution in various spheres of the Earth need refinement with more specific data of each continent where anthropogenic activities are continuously modifying the biogeochemical cycle of carbon on regular basis. Merely estimating total carbon in atmosphere or in any other natural Earth's sphere is not enough. It is necessary to understand the heterogeneity of carbon fluxes and the dynamics of their dissemination to model climate changes

There is need to have credible specific data on the carbon fingerprints in each eco-environmental set up related to each mega industrial source of carbon including the transport sector, each agricultural activity, each forest management practice and each forestation project, each infrastructural project that relates to modification of forest cover, coastal ecology and ecology of major water bodies.

There is also need of data which can help specifically quantify carbon budget in deep ocean regimes around the continents and help better define the dynamics of variations of carbon budget in nature as related to continuously changing annual rain fall patterns, discharge of river waters their carrying capacities of transport of terrestrial carbon into the sea.

Anything that can be measured can be managed. A specific credible data on the fate of carbon due to anthropogenic activities and due to variations in pristine set up of nature due to various natural factors will help generate meaningful, science based efficient approaches for carbon management to control climate change.

It is time that India has its own National Program for Carbon Management. The detailed casting of projects under this program would need a body of very experienced and mature scientists who after acquainting in detail about such programs in other parts of the world come out with very practical projects of critical nature along with their phases and time frames, human resources and competence required and costs structures to put India amongst the leading green and clean nations. The Department of Science and Technology and The Council of Scientific and Industrial Research are already encouraging initiatives of various individual scientists and organizations in the field of carbon management, carbon dioxide sequestration and clean development mechanism now need to redouble their efforts towards preparing and implementing and ruthlessly monitoring a top down program within a years time on an integrated national scale to prevent India from the vagaries of likely rapid climate change caused by green house gases, especially carbon dioxide.

# DEVELOPMENTS IN $CO_2$ SEQUESTRATION TECHNOLOGY

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The technology for $CO_2$ sequestration is fast developing and a lot of activity to launch pilot and demonstration projects in Carbon Capture and Storage (CCS) is taking place internationally. In India through government and industry support R and D efforts are being mounted. With a focused goal of dissemination of knowledge among its stakeholders from industry and academia, an awareness programme on carbon capture and storage was held at INSA very recently. This paper will describe the outcome and highlight developments in India vis-à-vis global advancements.

# COAL FORMATION-GEOLOGICAL AND GEOCHEMICAL ACTIVITY-THERMAL ENERGY IN INDIA

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Coal constitutes the most dominant constituent of the energy sector in India. In the year 2008-09, the coal production was over 490 million tones. Power Sector consumes almost 80% of the coal produced in the country.

India has abundant coal reserves of the order of 260 Billion Tones, most of these are high ash content coal in the calorific value range of 3000 kilo calorie per kilogram to 4,500 kilo calorie per kilogram and ash content in the range of 30 – 45%. The concentration, variation (both laterally and vertically), and modes of occurrence of trace elements are controlled by geologic and geochemical processes that begin in the peat stage and continue through coalification.

Understanding the distribution of trace-metal in coal is needed to:

- Develop models for power plant emissions.
- predict coal behavior upon cleaning.
- control release of metals from coal and coal combustion materials to ground water, and
- minimize health consequences of coal use in domestic settings.

Nearly all Indian coal power plants presently rely on one technology for converting coal to electricity: steam-based sub critical pulverized coal (PC) technology. Environmental concerns from coal mines and coal-based power plants are:

- dust propagation at the mines,
- pollution of local streams, rivers and groundwater from effluent discharges and percolation of hazardous materials from the stored fly ash,
- degradation of land used for storing fly ash, and
- noise pollution during operation.

However these are mitigated by the industry by taking appropriate remedial actions based on the well laid Environment Management Plan (EMP) and periodic monitoring. The other key environmental concerns in the coal-power sector in India include air pollution (primarily from flue gas emissions of particulates, sulfur oxides, nitrous oxides, and other hazardous chemicals); Furthermore, the inferior quality of Indian coal, with its high ash content and low calorific values, lead to increased particulate pollution and ash disposal problems. Regulations that limit pollution from power plants are focused mainly on particulate matter emissions and ambient air quality standards for sulfur oxides (SOx) and nitrogen oxides (NOx). The demand for electricity is so great that plants that violate the norms are not shut down, despite legal obligations to do so.

The geochemistry of coal becomes a handy tool to figure the root cause of the problem based on the coal quality and find out the path and means to overcome the various environmental problems arising. The inorganic (and in some cases, organic) constituents in coal may have profound effects on the health of those people burning coal in their homes or living near coal deposits, coal mines, or coal-burning power plants. However, Coal scientists and technologists are ideally positioned to help minimize health problems due to coal combustion by providing information on coal quality. The geochemistry also helps the technologists to explore the various possibilities for energy conversion through clean coal technologies from the fossil fuels.

## CLEAN COAL TECHNOLOGIESS (CCT'S)

The Clean Coal Technology programme aims to provide the information and update on various technological options for the efficient and cleaner utilization of coals i.e. for better energy conversion ratio and cleaner products.

Emerging CCT's can be divided into two broad areas:

- Improving coal burn characteristics and reducing emissions during the burning process and
- Using coal in other ways that fundamentally change the way its energy is exploited, as in gasification and utilization.

The first point about CCT is that there is a surprising range of coal quality available. In international markets, typical coal qualities range as follows:

- CV (kcal/kg) 5500-7500
- Ash (%) 6 -18
- Volatile Matter (%) 15-35
- Sulphur (%) 0.1-1.50
- Fixed Carbon 40-70
- Ash, sulphur and other potential contaminants are important and will become more so, but at present the heat value remains the fundamental value definer.

## COAL WASHING AND BENEFICIATION

One of the simplest and best-known techniques for reducing emissions is the washing of coal. The drying of coal is another beneficiation technique that aims at reducing the moisture content to ensure the heat availability in the boiler.

## COAL LIQUEFACTION

More modern techniques include investigation of alternative methods for converting low rank coals (LRC's) into economically viable liquid fuels. This led to the successful development of a direct LRC slurry liquefaction process at the Energy and Environmental Research Center (EERC) facility in Grand Forks, North Dakota, the world's largest research and development complex for investigating LRC's. The EERC developed an integrated close-coupled multi-step process to take advantage of the higher coal reactivity and moisture content of LRC's to produce a product that may be easier to upgrade than products from liquefaction of higher-rank coals. The process utilizes hydrogen donating solvents, the water–gas shift reaction, and lower-severity reaction conditions. Successful implementation of this process promises improved economic viability of low-rank coal liquefaction.

## FLUIDISED BED COMBUSTION (FBC)

FBC can reduce SOx and NOx by 90% or more and is very flexible – almost any combustible material can be burnt. In USA, FBC systems are increasingly used for abandoned coal waste, turning what could otherwise be an environmental problem into a useful source of power. This improves combustion, heat transfer and recovery of waste products. By elevating pressures within a bed, a high-pressure gas stream can be used to drive a gas turbine, generating electricity.

## $CO_2$ / CARBON CAPTURE SEQUESTRATION

Carbon capture and storage technologies allow emissions of carbon dioxide to be 'captured' and 'stored' i.e. they are removed from the exhaust gases of the power station (either from conventional combustion or from gasification), and stored in such a way that they do not enter the atmosphere – thus reducing global warming. Field tests and computer simulations have shown that the injected $CO_2$ will remain safely in underground. Carbon storage is not yet cost-effective, even when combined with Enhanced Oil Recovery (EOR).

However, the advent of large scale CO2 capture is probably still some way off, at least in terms of having any significant impact on coal demand. It is highly likely that carbon prices will rise significantly, but this will take some time, with prices rising in the next decade to a level still below that which would prompt power generators/other emitters to significant shifts towards CCS.

It is probable that CCS on a commercial scale is some way off and may be limited to certain regional areas where old oilfields have the capacity to store the gas effectively. India has joined the global initiative on Carbon Sequestration Leadership Forum (CSLF). As a matter of fact, India was one of the first 15 nations in the world, which signed the CSLF Charter in June 2003 and it is represented on the CSLF Policy and Technical Groups.

India's carbon emissions increased by 61 percent between 1990 and 2001, a rate surpassed only by China. India's greenhouse gas emissions are expected to jump between 4 BT and 7.3 BT in 2031. The per capita emissions are estimated to rise to 2.1 tonnes by 2020 and 3.5 tonnes by 2030 from the present level of 1.2 tonnes. The rise in India's carbon emissions is in part due to the low energy efficiency of coal-fired power plants in the country. High capital costs of replacing existing coal-fired plants, a scarcity of capital, and the long lead time required to introduce advanced coal technologies point to the likelihood that most of India's polluting coal-fired power plants will remain in operation for the next couple of decades. CCS is a critical option in the portfolio of solutions available to combat climate change, because it allows for significant reductions in $CO_2$ emissions from fossil-based systems, enabling it to be used as a bridge to a sustainable energy future.

## INTEGRATED GASIFICATION

In this system coal is not burnt directly, but is reacted with oxygen and steam to form a 'syngas' composed mainly of hydrogen and carbon monoxide, which is cleaned and then burned in a gas turbine to generate electricity and to produce steam to drive a steam turbine, also for electricity.

Before this technology can be widely deployed, the costs of IGCC (Integrated gasification combined cycle) and $CO_2$ capture must clearly be reduced and utility of such technology significantly improves the environmental performance of coal. IGCC technology may be the way towards an ultra-low emission in future, if combined with carbon capture and storage and as part of a future hydrogen economy.

## UNDERGROUND COAL GASIFICATION

The deep-seated coal reserves, which are not techno-economically amenable to mining at present, provide target area for various non-conventional methods of energy extraction, such as CBM, UCG etc,. For being profitable commercial venture, CBM, UCG etc, prospects need to conform several conditionality in regard to gas storage and transmitting capabilities of coal seams and also size of the prospect. The UCG provide considerable flexibility, which is in-situ gasification of coal seams through directional holes drilled from surface. It is cleanest of all coal based electric power technology. In India, UCG was taken up as national project in the early 80's. The product gas is mixture of hydrogen, carbon monoxide, methane, carbon dioxide and higher hydrocarbons. Calorific value in the range of 850 to 1200K.Cal/$NM^3$ for air injection

Practically unlimited supply of coal is available for gasification; no external supply is required to sustain the reaction. The UCG process creates an immense underground gas and heat storage capacity for stable gas supply. It can be transported to meet the needs of power generation, heat supply and feed stock for fertilisers, petrochemicals. The environmental benefits are minimum surface disturbances, no ash or slag removal and minimal site rehabilitation

## CBM FROM VIRGIN COAL SEAMS

The high-rank coal seams in deeper coalfields represent a significant target for future coal mine methane (CMM) and Coal Bed Methane (CBM) development. In some of the coalfields of the Damodar Valley, there are around 25 coal seams or even in excess of 40 in some areas, with cumulative thickness of over 100 meters.

Coal bed methane exploration and exploitation activities are still in the initial stages of research and development. Estimates of India's CBM potential vary. One source estimates up to 2 trillion $m^3$ of CBM in 56 coal basins covering 64,000 $km^2$. Coal in these basins ranges from high-volatile to low-volatile bituminous with high ash content (10 to 40 percent), and its gas content is between 3-16 $m^3$/tonne (Singh, 2002).

The Directorate General of Hydrocarbons estimates that deposits in 44 major coal and lignite fields in 12 states of India covering an area of 35,330 $km^2$ contain 3.4 trillion $m^3$ of CBM depending on the rank of the coal, depth of burial, and geotectonic settings of the basins.

India has been attempting to develop its CBM resources for several years. In 1997, the government formed a CBM policy that established the Ministry of Petroleum and Natural Gas as the CBM administrative agency and offered several incentives. The Indian government offered blocks for exploration and production of CBM through an international bidding process.

## CBM IN GODAVARI VALLEY COALFIELD

Coal exploration in Godavari Valley Coalfield is mostly confined only upto 600 m. depth; and there is no proposal to drill deeper boreholes beyond this depth in the near future.

Since the CBM content upto 600m depth is very low, ranging from 0.80 $m^3$/ tonne to 2.01 $m^3$ /tonne as against the economic viability of 8 to 15 $m^3$/ tonne; and in absence of CBM studies beyond 600 m. depth; it is difficult to conclude about the potential of CBM in Godavari Valley Coalfield at this stage.

However, keeping in view the vast aerial extent of coal bearing areas and occurrence of coal seams at greater depths upto 820 m. (as established in a few regional boreholes) and considering the gas increment rate of 1.3 $m^3$/ tonne per every 100 m. depth; it is desirable to plan for drilling deeper boreholes upto 1200 m. depth and beyond for a realistic Coal Bed Methane potential evaluation in Godavari Valley Coalfield / Andhra Pradesh.

Two blocks viz, GV (North)-2005/III and Kothagudem KG(E)- 2005/III were offered for CBM under third round of bidding(CBM-III)

Worldwide the awareness about the environmental pollution and its hazardous effects on human health is increasing. With increase in unit size and growing concern for the cleaner environment, the need has been realized world over.

Human activities have led to large increases in heat-trapping gases over the past century. The global warming of the past 50 years is due primarily to this human-induced increase. Global average temperature and sea level have increased, and precipitation patterns have changed. Human "fingerprints" also have been identified in many other aspects of the climate system, including changes in ocean heat content, atmospheric moisture, plant and animal health and location. Many types of extreme weather events, such as heat waves and regional droughts, have become more frequent and intense during the past 40 to 50 years. . Global temperatures are projected to continue to rise over this century. Unless the rate of emissions is substantially reduced, impacts are expected to become increasingly severe for more people and places.

# EVALUATION OF DECCAN CONTINENTAL FLOOD BASALTS, INDIA FOR GEOLOGICAL SEQUESTRATION OF $CO_2$

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Atmospheric accumulation of $CO_2$ is continuously increasing (The Green House Gas Effect) due to excess usage of fossil fuels in order to meet the ever-increasing energy demands the world over. This has triggered the well documented melting of polar ice caps, recession of glaciers in temperate regions and a slow but inexorable rise in sea levels. Carbon dioxide generated from point sources of emission like power and petrochemical plants and due to the combustion of fossil fuels, is considered the most significant component in the present day atmospheric gas accumulation. Petrochemical and fossil fuel based power plants contribute approximately one-third of the total emissions of carbon dioxide. But use of cheap and abundant fossil fuels will remain the vital component of the energy resource needed to sustain the enhanced economic growth rate of both the developed and developing worlds. One way of minimizing $CO_2$ emission into atmosphere, is by the capture and storage of $CO_2$ produced at the point sources itself. A viable option to mitigate the hazardous consequences of such an accumulation is the deep underground storage / sequestration of $CO_2$ in geological formations. Proposed deep seated geological methods for sequestering $CO_2$ include terrestrial and ocean sequestration. Among the terrestrial sequestration methods, mineral carbonation/ mineral trapping is an effective and a permanent technique especially in mafic-ultramafic rocks, in which injected $CO_2$ reacts with Fe, Mg and Ca-rich minerals constituting the host rock, in the presence of formation waters to form solid carbonates which are stable and bind $CO_2$ over geological time. Underground storage of large quantities of $CO_2$ in relatively porous and permeable reservoirs requires an assessment of the geological suitability of the host rock(s) defining the storage site and security of storage. Such a deep seated storage will entail underground retention of $CO_2$ either as a supercritical phase or a trapped solid phase over geological time scales to enable the natural buffering processes to take effect.

Laboratory simulation experiments and field studies on a pilot scale towards geological $CO_2$ sequestration are underway at present on a priority basis all over the world including India. With this aim, our preliminary studies carried out have shown that the mafic - ultramafic rocks constituting the Deccan Volcanic Continental Flood Basalt Province in west-central India, having appreciable concentrations of iron, magnesium and calcium bearing primary silicates, can constitute one of the potential reservoir systems for underground geological sequestration of $CO_2$. Immediately after injection, $CO_2$ stored initially as a free phase, gets dissolved in the local formation water, initiating a variety of geochemical reactions, controlled by the mineralogy, chemical composition of the specific lithological suite and P-T. Most of the lava flows in the Deccan Flood Basalt Province have amygdular flow tops and bottom as well as interflow features, imparting the required porosity and permeability for $CO_2$ diffusion and storage. Under suitable conditions of temperature and pressure and local formation water's pH, the injected $CO_2$ interacts with iron, magnesium and calcium released due to reaction with primary Fe-Mg and Ca bearing minerals such as pyroxene, olivine, plagioclase and glass especially at low pH, to form geologically stable ferrous, magnesium and calcium bearing carbonates. Laboratory simulation experiments conducted over 5 months period by reacting accurate quantities of injected supercritical $CO_2$ in titanium P, T vessels having known amount of water and picritic basalt samples collected from the Igatpuri area in Maharashtra coupled with SEM-EDS studies, confirm the following exothermal mineral carbonation reactions effectively trapping the injected $CO_2$.

(a) $2Mg_2SiO_4$ (Olivine) + $CO_2 + 2H_2O \rightarrow Mg_3SiO_5(OH)_4$ (Serpentine) + $MgCO_3$ (Magnesite) and

(b) $CaAl_2Si_2O_8$ (Plagioclase) + $2H_2O + CO_2 \rightarrow CaCO_3$ (Calcite) + $Al_2Si_2O_5$ (OH) (Clay).

# CARBON NATURAL TECHNOLOGIES AND CARBON SEQUESTRATION / RECYCLING TECHNOLOGIES, THEIR CONTEMPORARY RELEVANCE AND TECHNOLOGICAL BARRIERS

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There are many routes for perusing the Carbon Neutral Technologies by adopting Carbon Sequestration/ Recycling Technologies to separate and sequester $CO_2$ and reduce GHG's which has become a global objective.

**Carbon Neutral Technologies**

Plantation of Energy Plantation's on 7 million Ha. Out of the 15 million Hectare of degraded forest lands in India would produce Biomass obtained by pruning and copping and would be equal to 380-400 Million tons of Coal equivalent fuel per year . These Energy Plantations could produce 70,000 MW of Carbon Neutral Power Plants. These plants would be eligible for Carbon Credits. This quantity of Biomass from Energy Plantations would be used by a process of Hydro- gasification of Biomass to produce Methane (CNG) and Power from waste heat. Apart from this the Biomass obtained by pruning and copping would be equal to 380-400 Million tons of Coal equivalent fuel per year. This entire Carbon Neutral Process of energy production would result in production of 70,000 MW of Power and 250 Million tons of Methane while directly employing about 6-8 corers people effecting in all a population of 32 corer Indians.

**Carbon Recycling Technologies**

Carbon Recycling Technologies set forth objectives of development of processes which use the Carbon of $CO_2$ to produce useful fuels like Hydrogen, Methane and Methanol. The latest technological frontiers, their relevance and limitations.

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# EMERGING TRENDS IN THE SEQUESTRATION OF $CO_2$ - ROLE OF GEOMICROBIOLOGY, BIOSEQUESTRATION AND INDUSTRIAL APPROACHES

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Several approaches for the sequestration of $CO_2$ for carbon management are being proposed. These include geological, biochemical, chemical, physical, oceanic and other. techniques. There is a need to find out some cost effective and permanent solution for $CO_2$ sequestration. Some of the biochemical approaches may be combined with geoengineering or chemical approaches. Biosequestration of $CO_2$ includes not only the production of algae (for biodiesel and $H_2$) but also further enhancing the growth of certain faster growing plants and trees by a synergy between microbial and biological systems. There are certain bacteria such as chemoautotrophic bacteria which can utilize $CO_2$ instead of carbohydrates for their growth. Such bacteria are already being utilized for the copper, gold, uranium etc. metallurgy in industries. Studies on geomicrobiology and geochemistry are important for developing the techniques of utilization of $CO_2$ by the chemoautotrophic bacteria present in mines and their interactions with metal bearing minerals. Microbial dolomite process has been studied and even high pressure chemical reactions have been studied for the dolomite formation. Microbially enhanced geologic containment of geologically sequestered $CO_2$ under supercritical conditions by biofilm formation has been studied. Microbiogeochemical processes involved in the formation of dolomite in saline lakes using atmospheric $CO_2$ have also been reported. There appears to be a wide scope of using the bacteria in an integrated processes of geobacterial mining-metallurgical processes. Role of biosequestration along with industrial operations for either biohydrometallurgy, refining of fossil fuels or waste treatment for $CO_2$ sequestration would be discussed during the presentation. Ultimately a combination of different techniques would help in carbon management.

# SESSION - III

# CARBON SEQUESTRATION AND MANAGEMENT (CONTINUED)

## CAN OCEAN FORESTS BECOME REALITY AS SINK FOR ATMOSPHERIC $CO_2$?

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Oceans cover ~71% of the planet Earth's surface area. Although ~50% of the human population lives in a coastal area not farther away from the coastline than 10 km, the ability of the Oceans to bear the brunt of civilization is not fully realized except in dumping anthropogenic wastes into the coastal area indiscriminately. Beyond the coastal area, the seas could be used to set up huge floating farms with nets where macro-algae is grown for multiple uses, a concept being trial implemented in Japan.

Another intensely pursued option currently is Ocean Iron Fertilization (OIF). Although hotly debated, and the controversies associated with this technique, OIF has attracted intense interest of scientists, governments and industry. Credited with a biological 'must' and unique redox chemistry, Fe is in deficit in the nutrient rich but productivity poor waters that surround the Antarctica and extend over an area equivalent to ~20% of the global oceanic surface. If the cheap Fe were to be supplied by human intervention, these waters would fix as many as ~3000 moles of $CO_2$ for every Fe atom added. Large scale experiments, ten so far, including the latest LOHAFEX experiment by joint collaboration of India and Germany have been conducted. The results are very encouraging but there are apprehensions galore. Those are chiefly: (i) recycling of fixed carbon within the upper water column on time scales of 1-10 years when $CO_2$ returns to the seawater, (ii) the efficiency of carbon burial in the deep sediments, (iii) drastic changes in ecosystem and its balance, (iii) production of harmful nitrous oxide ($NO_2$) and methane ($CH_4$) gases that have several fold greenhouse warming effect than $CO_2$, since they diffuse from oxygen minimum zone (OMZ), intensified due to the enhanced production at surface up into the atmosphere, etc. The various options available for $CO_2$ mitigation and their pros and cons are highlighted.

## STATUS AND RELEVANCE OF CARBON CAPTURE AND STORAGE IN EMERGING ECONOMIES: INDIA'S PERSPECTIVE

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India is an emerging economy and to sustain our GDP growth of 6-7%, our energy requirement is likely to go up by 5-6%. Energy scenario in India is mostly driven by coal, oil and gas. The coal based thermal power stations are the largest point sources of carbon dioxide emissions in the atmosphere and its increased level in the atmosphere has been implicated in global warming which is not a myth but truth.

The capture of carbon dioxide from point sources and its storage in the geological formations such as deep saline aquifers, basalts, depleted oil and gas reservoirs for enhanced recovery, organic shales and unmineable coal seams are most viable alternatives to mitigate the impact of climate changes. The cost of carbon capture and storage (CCS) is 3-4 times higher the carbon credit.

R and D issues for CCS and their relevance to meet the challenges of global climate changes vs. strategic development for emerging economies will be discussed and presented. Issues for carbon dioxide management in India will also be deliberated.

# CARBON-ALUMINA COMPOSITE MATERIALS AS ADSORBENTS FOR CARBON DIOXIDE CAPTURE

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Carbon and alumina have both advantages and disadvantages as adsorbents. In order to incorporate the advantages of both these materials, an attempt has been made to synthesise carbon -alumina composites with different ratios of activated carbon and alumina by precipitation-deposition technique. These materials were charectrized by BET surface area and XRD, and their sorption capacity was estimated by $CO_2$ pulse chemisorption. It is observed that g - alumina has more CO-$_2$ adsorption capacity than activated carbon. The carbon - alumina composite materials possessed higher surface area than the corresponding material prepared by physical mixing of carbon and alumina with similar loading. It is interesting to observe that the composite materials with lower carbon content contain predominantly boehmite phase and the materials with relatively higher carbon content ($\geq$ 25 % by weight) contain predominantly g - alumina phase. The composites with $\geq$ 25 % by weight of carbon possess higher $CO_2$ adsorption capacity which may be due to the presence of well dispersed g - alumina phase on carbon. Particle size of g - alumina is one of the important parameters in storing higher $CO_{2-}$. The temperature programmed desorption studies indicate that the carbon-alumina composite material with ~ 25% carbon content is highly useful to act as a carbon dioxide adsorbent.

*Keywords* : Carbon Supported Alumina adsorbents, Combined Characteristics, $CO_2$ Adsorption, g-Alumina, Boehmite.

# CARBON DIOXIDE IN THE NORTH INDIAN OCEAN

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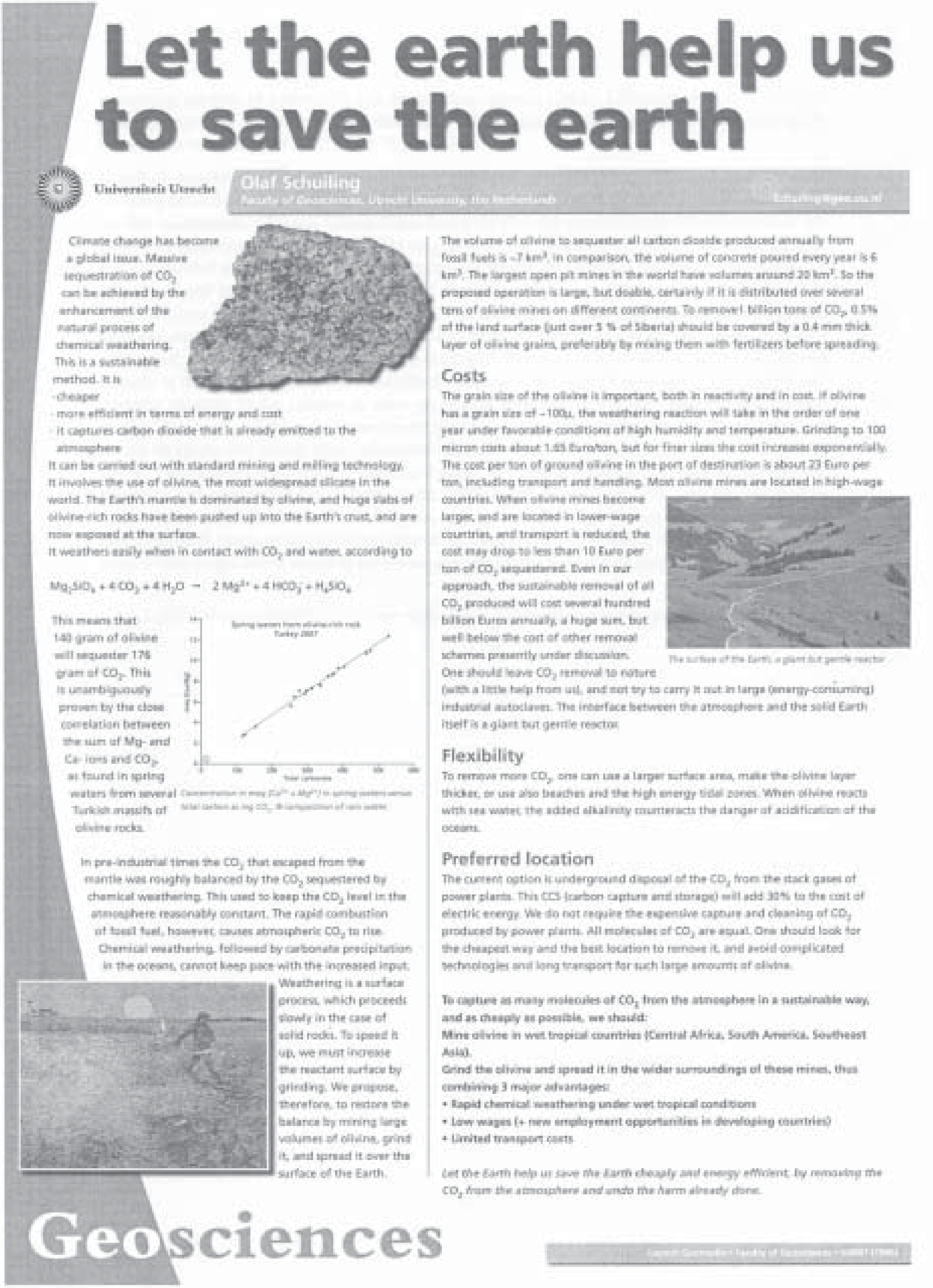
The oceans modulate the atmospheric carbon dioxide contents from time to time. Biological cycling assumes significance as the synthesis of organic matter at the surface facilitates storage of carbon in the deep ocean through sinking particles. The North Indian Ocean is one of the most productive regions of the world and particularly so during summer monsoon. Relatively higher productivity followed by regeneration of organic materials leads to oxygen deficiency in the water column, in general. The oxygen deficiency facilitates denitrification process in the Arabian Sea but not in the Bay of Bengal. As a result of differences in organic material cycles the Arabian Sea is found to perennially emit carbon dioxide to atmosphere whereas the Bay of Bengal acts as a seasonal/coastal sink. Nevertheless, sinking of organic materials from the Bay of Bengal water column is aided by atmospheric and riverine transports of clay minerals from land. Regeneration of carbon particulates makes the North Indian Ocean deep and bottom waters a significant reservoir of carbon storage in the world oceans. Consequently, the atmospheric carbon dioxide is transferred faster in the Indian Ocean facilitating its longer storage in the deep oceans.



# Let the earth help us to save the earth

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Climate change has become a global issue. Massive sequestration of $CO_2$ can be achieved by the enhancement of the natural process of chemical weathering. This is a sustainable method. It is

- cheaper
- more efficient in terms of energy and cost
- it captures carbon dioxide that is already emitted to the atmosphere

It can be carried out with standard mining and milling technology. It involves the use of olivine, the most widespread silicate in the world. The Earth's mantle is dominated by olivine, and huge slabs of olivine-rich rocks have been pushed up into the Earth's crust, and are now exposed at the surface.
It weathers easily when in contact with $CO_2$ and water, according to

$$Mg_2SiO_4 + 4\,CO_2 + 4\,H_2O \rightarrow 2\,Mg^{2+} + 4\,HCO_3^- + H_4SiO_4$$

This means that 140 gram of olivine will sequester 176 gram of $CO_2$. This is unambiguously proven by the close correlation between the sum of Mg- and Ca- ions and $CO_2$, as found in spring waters from several Turkish massifs of olivine rocks.

In pre-industrial times the $CO_2$ that escaped from the mantle was roughly balanced by the $CO_2$ sequestered by chemical weathering. This used to keep the $CO_2$ level in the atmosphere reasonably constant. The rapid combustion of fossil fuel, however, causes atmospheric $CO_2$ to rise. Chemical weathering, followed by carbonate precipitation in the oceans, cannot keep pace with the increased input. Weathering is a surface process, which proceeds slowly in the case of solid rocks. To speed it up, we must increase the reactant surface by grinding. We propose, therefore, to restore the balance by mining large volumes of olivine, grind it, and spread it over the surface of the Earth.

The volume of olivine to sequester all carbon dioxide produced annually from fossil fuels is ~7 km³. In comparison, the volume of concrete poured every year is 6 km³. The largest open pit mines in the world have volumes around 20 km³. So the proposed operation is large, but doable, certainly if it is distributed over several tens of olivine mines on different continents. To remove 1 billion tons of $CO_2$, 0.5% of the land surface (just over 5 % of Siberia) should be covered by a 0.4 mm thick layer of olivine grains, preferably by mixing them with fertilizers before spreading.

## Costs

The grain size of the olivine is important, both in reactivity and in cost. If olivine has a grain size of ~100μ, the weathering reaction will take in the order of one year under favorable conditions of high humidity and temperature. Grinding to 100 micron costs about 1.65 Euro/ton, but for finer sizes the cost increases exponentially. The cost per ton of ground olivine in the port of destination is about 23 Euro per ton, including transport and handling. Most olivine mines are located in high-wage countries. When olivine mines become larger, and are located in lower-wage countries, and transport is reduced, the cost may drop to less than 10 Euro per ton of $CO_2$ sequestered. Even in our approach, the sustainable removal of all $CO_2$ produced will cost several hundred billion Euros annually, a huge sum, but well below the cost of other removal schemes presently under discussion. One should leave $CO_2$ removal to nature (with a little help from us), and not try to carry it out in large (energy-consuming) industrial autoclaves. The interface between the atmosphere and the solid Earth itself is a giant but gentle reactor.

The surface of the Earth, a giant but gentle reactor

## Flexibility

To remove more $CO_2$, one can use a larger surface area, make the olivine layer thicker, or use also beaches and the high energy tidal zones. When olivine reacts with sea water, the added alkalinity counteracts the danger of acidification of the oceans.

## Preferred location

The current option is underground disposal of the $CO_2$ from the stack gases of power plants. This CCS (carbon capture and storage) will add 30% to the cost of electric energy. We do not require the expensive capture and cleaning of $CO_2$ produced by power plants. All molecules of $CO_2$ are equal. One should look for the cheapest way and the best location to remove it, and avoid complicated technologies and long transport for such large amounts of olivine.

**To capture as many molecules of $CO_2$ from the atmosphere in a sustainable way, and as cheaply as possible, we should:**
**Mine olivine in wet tropical countries (Central Africa, South America, Southeast Asia).**
**Grind the olivine and spread it in the wider surroundings of these mines, thus combining 3 major advantages:**

- **Rapid chemical weathering under wet tropical conditions**
- **Low wages (+ new employment opportunities in developing countries)**
- **Limited transport costs**

*Let the Earth help us save the Earth cheaply and energy efficient, by removing the $CO_2$ from the atmosphere and undo the harm already done.*

Geosciences

# SESSION - IV
# CLIMATE AND CARBON

## OLIVINE AGAINST CLIMATE CHANGE AND OCEAN ACIDIFICATION

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A novel way to combat climate change is proposed, by using the common mineral olivine, not as a chemical in a technology, but in the same way it works in nature. Chemical weathering of olivine and other calcium and magnesium silicates has always been the main mechanism to keep the $CO_2$ levels of the atmosphere within reasonable bounds, with storage of organic carbon a distant second.

At present these mechanisms cannot cope with the increased input of $CO_2$ caused by the burning of fossil fuels. In order to reach a new balance we should seek to reduce $CO_2$ emissions, but should also consider increasing the rate of weathering. This can be done by mining abundant rock types that weather easily, grinding them, and spreading the powder in a thin veneer over large areas in wet tropical climates where weathering rates are highest. This will also improve the quality and productivity of the soil, as it adds valuable mineral nutrients.

The reaction that is relevant to combat climate change is the transformation of $CO_2$ into bicarbonate in solution. Ultimately these bicarbonate solutions will reach the oceans and precipitate as carbonate sediments, but this is a slow process which extends well beyond the time span of concern. Some considerations on rates of weathering, based on observations from geology and soil science are given. They turn out to be considerably higher than rates calculated on the basis of abiotic laboratory experiments.

Considerable pressure is being exerted on major rapidly industrializing nations like India, China and Brazil to limit their $CO_2$ emissions. However they fear that will hamper their economic development. If instead of limiting their emissions they can compensate them by capturing large volumes of $CO_2$ through the mining, milling and spreading of olivine, it will be much easier for these nations to join a new Kyoto agreement. All three mentioned nations possess large deposits of olivine-rich rocks. The use of their own resources and workforce, leading to a cost between 10 and 15 Euro per ton of $CO_2$ is vastly more acceptable than paying between 70 and 100 Euro per ton for carbon capture and storage, and having to import part of the required technology.

There is also a case to be made for the inclusion of $CO_2$ sequestration by accelerated olivine weathering in the Clean Development Mechanism of the Kyoto Protocol, subject to the CDM's extension in the current round of international climate negotiations.

## INJECTION OF $CO_2$ FOR ENHANCED OIL RECOVERY

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Carbon dioxide emission is known source of environmental pollution. There are many sources of huge $CO_2$ emissions. There is dire need to tap this $CO_2$ emission and store in such a place so that environmental pollution can be avoided. Recent study has shown that storage of $CO\text{-}_2$ in oil reservoir can give additional benefit of enhanced oil recovery. There are several other ways of enhanced oil recovery; however using $CO_2$ has dual benefit of enhancing the oil recovery as well as a potential remedy for environmental pollution.

NGRI has demonstrated a success story of enhanced oil recovery using a geophysical tool called time lapse (4D) seismic in similar framework where in-situ combustion is used instead of $CO_2$. The same concept of 4D seismic can be extend for monitoring of injected $CO_2$ in oil reservoir or any suitable sub-surface geological trap. Time lapse seismic is efficient tool for monitoring and developing of any subsurface change with time. Often monitoring depends on physical characteristic of reservoir but in most of the sand reservoirs this technique is proven and has given excellent results.

## CLIMATE CHANGE AND IMPACT ON GROUND WATER-NEED FOR RESEARCH AND INVESTMENT

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## IMPACT OF CARBON ON CLIMATE

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Carbon in the form of carbon dioxide and methane plays key role in shaping the climate because these are greenhouse gases. It is widely publicized that the present industrialization and fossil fuel burning is the major cause of global warming and climatic changes. The climatic changes are mainly considered to be due to greenhouse effect. The greenhouse effect is causing global warming is widely acceptable, however, the concentration of carbon and methane in atmosphere depends upon a number of variable factors like volcanic outgasing, fossil fuel burning, decomposition of organic matter, capacity of the ocean of holding the $CO_{2,}$ photosynthetic activity etc. So much so that the natural causes are more responsible for global warming than the anthropogenic contribution. The five major glacial cycles in earth's history also indicate the five warmer periods as well. The earlier five warmer period were definitely non anthropogenic, thereby indicating that the climatic changes are more of the natural phenomenon.

It is believed that the initial carbon content of the earth was very low. Soon after this stage as the planetisimal (small bodies formed from the solar nebula and carbon containing meteorites bombarded the solid earth the carbon content progressively increased, so much so that the high $CO_2$ content of the atmosphere protected the earth from freezing, as because at that time the luminosity of sun was low.

Subsequently, carbonic acid (formed from combination of $CO_2$ and $H_20$ ) has slowly but continuously combined with calcium and magnesium in the crust through weathering process to form insoluble carbonates, thereby reducing the then existing carbon dioxide from the atmosphere. But there was replacement of $CO_2$ due to volcanic and tectonic activity, till the emergence of cynobacteria.

Role of organic process in carbon cycle was initiated with the origin of life sometime around 3500 million years ago in the form of cynobacteria which released oxygen after consuming carbon dioxide. The increased presence of oxygen also started destroying methane present at that time, resulting into overall reduction in greenhouse effect. The reduction of carbon dioxide and methane in the atmosphere gradually paved way for first glaciation to occur around 2700 Ma (the beginning of first glacial cycle. The first glaciations between 2700Ma to 2300Ma is known as **Huronian Glaciations.**

Following the Huronian Glaciation, the climate once again became very warm, which continued up to 750 million years, although no one quite knows why. However, the presence of massive volcanic rocks found from this period is indicative of profuse volcanic activities, which was possible reason for global warming at that time.

Evidence of new glaciations has been found in rocks dating 750 and 580 million years ago. There were probably a number of different glacial periods, each one lasting several million years. It is believed that there were three main glacial periods: the **Sturtian,** which took place around 710 Ma; the **Marinoan,** which took place around 635 Ma; and the **Varangian,** which took place around 600 Ma.

The late-Proterozoic glaciations were followed by minor series of glaciations from 460 Ma to 430 Ma marking the boundary of Ordovician and Silurian Periods accompanied by major extinction event. After this there are indications of Permocarboniferous glaciations (250-300 Ma).

The latest glaciations called the Quaternary glaciations have seen more or less cyclic glaciations initially at 40,000 and later at 100,000 years intervals.

Presently we are in Holecene interglacial phase of Pleistocene glaciations. The alternating glacial and interglacial periods show good correlation in the temperature and $CO_2$ content as deduced from isotopic analysis of ice core samples going back to 650,000 years. The correlation between low $CO_2$ content in the atmosphere and glaciations is not so perfect for example the late-Ordovician period was also (an ice age while at the same time $CO_2$ concentration were nearly 12 times higher than today – 4400 ppm. According to greenhouse theory, earth should have been exceedingly hot. Instead, global temperatures were no warmer than today. There by clearly indicating the role of other factors besides the influence of atmospheric carbon influence to increase earth temperatures and global warming.

The paper deals with all the possible reasons of global warming and climatic changes such as (i) earth's orbit, (ii) solar output, (iii) biogenic activity and (iv) solar orbit in the galaxy and of course the (v) plate tectonics.

## GHG ACCOUNTING

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## EFFECTS OF CARBON EMISSIONS FROM LIME BASED INDUSTRIES IN AND AROUND SANKARNAGAR, TIRUNELVELI DISTRICT IN TAMILNADU, ON CLIMATE – AN APPROACH

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Carbon dioxide ($CO_2$) emission is produced as a by-product of non-energy related industrial activities and product uses. One of source of $CO_2$ is during the production of cement. Raw materials such as naturally occurring calcium carbonate/limestone are chemically transformed producing $CO_2$ as a byproduct. The cement industry in India has been enjoying its period with a healthy growth in demand for the years. The domestic consumption of cement grew by 9.8% compared to previous two financial years for 2006-2008. The clinker used for cement and lime production has grown up by 6.5% to 129.70 million tones in 2007-08 as compared to 121.75 million tones for the previous year, in India. The India Cements Ltd is a leading producer of cement in India, has one of its cement plant at Sankarnagar in Tirunelveli district of Tamilnadu, installed during 1949. The Tirunelveli district is located on the southern part of Tamilnadu in India, has an average elevation of 47 meters (154 feet) in the southern most tip of the Deccan plateau in the Indian peninsular. Limestone being the basic raw material for the production of Clinker for Cement and for other lime based products such as Quick lime, burnt lime, etc., the limestone mining activities in Tirunelveli district dates back to 18th Century. The limestone mines and the lime based industries are located in and around Sankarnagar in parts of Tirunelveli and Palaymkotai districts of Tirunelveli district. Around 75 mining leases are worked in the district meant for production of limestone. There are more than 200 lime-based industries in the district worked for the production of cement, burnt lime (locally known as Cem) and other related products. The burning of limestone along with other fuels such as Charcoal, Fuel Oils, Coal, lignite, etc., in and around Sankarnagar, forms a focal point for the emission of Carbon Dioxide ($CO_2$) and heat into the atmosphere. Sankarnagar in Tirunelveli district is a hot place. The highest temperatures around 37°C during April and with lower temperatures up to 19°C are recorded. The mean maximum and mean minimum are around 30° to 32°C to 22° to 25°C respectively, indicating that winter does not lower the temperature. Continues emission of $CO_2$ and heat from these lime based industries causing further damage to the climate. As it is known, Carbon management is one of the greatest challenges on environment, here an approach is made to study the status of unplanned mining and utilization of limestone for the production of lime based products leading to emission of heat and carbon dioxide in to the atmosphere. The study area is falling in the coordinates of 77° 33’ 75’’ to 77° 44’ 56’’ North latitude and 08° 55’ 23’’ to 08° 46’ 35’’ East longitude on Toposheet No.58H/9 of Survey of India. The available Remote Sensing Satellite Data as well as the Global Positioning System (GPS) is used for the mapping of Lime based industries in and around Sankarnagar.

## IMPACT OF GLOBAL WARMING ON AGRO ECONOMY AND CHANGING WEATHER CONDITIONS

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Abnormal warming of earth’s atmosphere due to various human activities and interference in natural ecosystem in an urge for creating better living conditions has its unrecoverable impact on seasonal cycle. The continuous hydrocarbon burning since man discovered fire to meet his growing energy demands has led to slow but steady heating up of globe. Added to this massive deformation mining and excavation had resulted in disturbing the delicate eco-balance leading to unseasoned and abnormal weathering conditions. Severe and continuous drought, heavy cyclone rains frequent depressions and low-pressure conditions, melting of glaciers, disturbance in mid ocean region which is the womb of weather activity are some of the after effects of unrelenting global warming. All or few of these disturbances have severely affected the agriculture activity, which is the backbone of rural economy in India. Agriculture is rain dependant, either for rain fed or surface water irrigated crops. Rain is the primary source of water; any disturbance in the incidence of precipitation has its long-lasting impact not only on agriculture but entire rural economy, recent most unfortunate incidence of farmers’ suicides is one such example. To asses and analyze the reasons which could have forced farmers who are the food providers for the Nation has led to conclusion that global warming had its saddening effect on the farmers life. Failure of monsoon and unseasoned rains specially during harvesting time, which in all probability is the recent phenomenon of global warming, hit hard the farming community. In Prakasam district alone 157 cases of farmers’ suicides have been recorded in the decade between 1998 and 2008. Close studies of N and NE mandals of the district, which have surface water irrigation facility, fertile BC soil, indicate that 36 farmers have resorted to self-killing. Net area sown constitutes 73% of total geographical area reflecting that agriculture is main occupation of majority of the population in these mandals. 35% of the gross area sown is in kharif where as it forms 65% in rabi indicating high dependence on rainfall as the district receives equal quantum of rain in SW and NE monsoons. The net area irrigated is only 24% of the net area sown in the eight mandals where as it is just 4% in Yaddanapudi mandal where ten farmers have committed suicide. Area under ground water irrigation constitutes 25% and rest by surface water sources. Timely and even distribution of rain fall is very crucial in these mandals for carrying out agriculture activity. These mandals being close to seacoast have to face the vagaries of abnormal coastal climate. The annual rainfall data for the past 18 years (1990-2007) shows below normal rainfall in 11 years leading to drought conditions. During years 2001-05, when maximum suicides (21) were reported, these have received as low as -78% of Normal rainfall and area average varies from -4 to -44%. The monthly rainfall data of the past decade indicates unseasoned rains in harvesting months of January/February or October/November months damaging the standing crops. These abnormal weather conditions also resulted in inquest of unexpected pests, crop diseases etc., to control these side effects the farmers have o invest more money in buying pesticides and fertilizers. Failure of standing crops severely affected the financial and moral capabilities of the ryots. Especially marginal farmers who constitute 68% of farmers and those who have taken the land on lease have drowned in debts beyond recovery. The study area is bestowed with fertile soil but ground water resources are very poor and water is not suitable for irrigation due high mineralization hence farmers opt for rain fed cash crops like tobacco, cotton, chilies, pulses etc., which require heavy investments. The copping pattern shows that pulses form 35%, chilies 4%, cotton 3%, tobacco 4% of the gross areas sown. Abnormal weather conditions have severe impact on these crop productions resulting in the farmers loosing not only their complete investment

but also lively hood. In the year 2004-2005 many farmers have committed suicides, the year had received lowest rainfall within the decade of 1999-2008. The Eddanapudi mandal, which had recorded highest farmer suicides, had received only 378mm rainfall in the year 2004-05. Apart from low rainfall, untimely rainfall in the form of cyclonic storms during harvesting periods resulted in damage to crops and total loss of investments. The low and untimely precipitation, abnormal weathering conditions could be the result of slow but steady raise in earth's atmospheric temperature which had jeopardized the lives of farming community. The alarming global warming phenomenon could be the beginning of the end of biomass on the planet earth if immediate preventive measures are not initiated worldwide. Increase in global temperature due to abnormal combustion of fossil fuels, massive environment destruction could trigger disastrous nature destructive mechanism in the form of sever cyclone, earth quake, tsunami, continuous drought challenging the continuation of very existence of life on the earth.

*Keywords* : Global warming, Unseasoned rains, Farmers suicides, Abnormal weathering conditions, Prakasam district.

## ALGAE: A MOST SUITABLE TOOL FOR ARRESTING GLOBAL WARMING AND SOURCING BIO-DIESEL

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Global warming and Climate Change have become most important and highly vulnerable topic of the day threatening very existence of human life on earth. The role of Carbon Di-oxide and use of fossil fuels in this is also well established.

Algae – an acellular, fastest growing, photosynthetic plant micro organism growing every where in saline, freshwater, arid or deseart habitate has now been established as an ultimate source as well as alternate for future energy. It reduces carbon from atmosphere by fixing huge quantity of $CO_2$ emitting from fossil fuel sourceslike power, steel and cement plants. It also removes $NO_2$ by about 86% and helps in providing a pollution free environment.

With the increasing interest in biodiesel as an alternative to petro-diesel, many have looked at the possibility of growing more oilseed crops as a solution to the problem of peak oil. There are two problems with this approach: first, growing more oilseed crops would displace the food crops grown to feed mankind. Second, traditional oilseed crops are not the most productive or efficient source of vegetable oil.

Algae completes its life cycle within a very short period of few days in contrast to other annual and traditional oil seed crops which are less productive. Algae farming is possible using aquatic species programme of NREL in open outdoor race track ponds using latest technology of Light Immersion Technology (LIT) whereby growth of more than a meter has been achieved in open ponds by either natural or artificial sources. Green fuel photobioreactors, a closed system can also be used. This overcomes the phenomenon of self shading and thus increases the yields by 30-40% and becomes only economically feasible approach.

It has been estimated that algae has the highest yield of Gallons of oil per acre per year of 5000-15000 in comparison to others like corn 18; Soyabean 48; Sanflower 83; Rapeseed 127; Palm Oil 635. It has been calculated that one rectangular piece of 120 mile by 125 miles can produce enough algae to meet the demand of all the ground transport of USA which is about 67% of total US oil consumption.

Based on the above data, it has been estimated that total cost of producing 140.8 billion gallon of unrefined oil for biodiesel would be about 46.2 Billion US $ compared to 100150 billion US $ that US currently imports.

GreenFuel Technologies in Cambridge, MA is field testing a closed system that uses the $CO_2$ in power plant flue gases (13% of flue gases in the test) to feed algae. (3,4) In so doing, it significantly reduced the $CO_2$

concentration in the exhaust by 82.3% (+/-12.5%) on sunny days and by 50.1% (+/- 6.5%) on cloudy days during the beta-test at the Cogeneration Plant at MIT. (5) The process also removed 85.9% (+/- 2.1%) of nitrogen oxides. And, not only will the GreenFuel Bioreactors reduce carbon and NOx emissions, but the company estimates the cost of a full-scale system installation to be 20% to 40% less than that of a comparable SCR system (pollutant scrubbers).

Using technology licensed from a NASA project, GreenFuel constructs triangular-shaped bioreactors from polycarbonate tubing two to three meters long and 10-20 cm in diameter. The hypotenuse of the triangles face the sun. Flue gases are introduced at the bottom of the hypotenuse and flow up while the media containing the algae flow in the opposite direction. From 15% to 30% of the algal media are harvested each day. The use of tubes in which to grow the algae overcomes the usual surface area limitation of ponds. In this case the turbulent mixing of the algal media with $CO_2$ in the tubes and the speed at which the fluid moves determine how fast the algae grow.

# SESSION - V
# HYDROCARBONS

# OLIVINE, SOME FUTURE DEVELOPMENTS

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In several potential applications, olivine can do more than capture $CO_2$, and some of these future developments will be described here. By the anaerobic digestion of organic wastes biogas is produced. Its composition is often around 2/3 methane and 1/3 $CO_2$, with traces of $H_2S$. For a high quality fuel, it is imperative to remove the $H_2S$ and reduce the $CO_2$ content. When we added olivine powder to the digester, it was found in preliminary experiments that the smell was suppressed (removal of $H_2S$), that the amount of methane increased and that the $CO_2$-content of the biogas decreased. These three results can be explained as follows:

- $CO_2$-content was reduced because it was partly converted to bicarbonate in solution by the weathering reaction of olivine
- $H_2S$ was precipitated as an iron sulfide by reaction with the fayalite molecule in the olivine ($Fe_2SiO_4$).
- Additional methane was formed by the reaction of fayalite with $CO_2$ and water, according to

$$3\ Fe_2SiO_4 + CO_2 + H_2O \longrightarrow \mathbf{CH_4} + H_4SiO_4 + Fe_3O_4$$

This last reaction is sometimes found in nature, where methane flames are emitted by serpentinizing dunites. Research on optimizing the volume and quality of the biogas is continuing.

More speculative, but potentially with a larger impact on future energy supply is the following. Diatoms make up 20 to 25% of the marine biomass. They consist for up to 50% of lipids, making them an excellent starting material for biofuel production. They are silica-limited. This is where olivine comes in. The effluents of the olivine reaction are rich in silica, with concentrations several times higher than the equilibrium concentration for quartz solubility. We can create diatom farms, by making lagoons behind an artificial sand bar made of olivine sand. The silica-rich effluent of an olivine operation will be released in the lagoon. This effluent may derive from large digesters, to which fine olivine powder was added. By eliminating the silica limitation, we will grow quasi monocultures of diatoms in the lagoon. The sand bar should have one or several U-shaped tubes connecting the lagoon with the open sea, permitting sea water to enter the lagoon during high tide, and drain it during low tide. These U tubes will be closed on the lagoon side by a metal net supporting a plankton net. During ebb, the diatoms will be carried seaward by the outflowing current, but will be trapped on the plankton net, and can be harvested. Contrary to land-grown biofuel crops, diatoms do not compete with food production, and will not require vast amounts of scarce irrigation water.

Another combination of $CO_2$ capture involves the phytomining of nickel. Olivine rocks are low in most heavy metals, but have somewhat elevated contents of nickel. Their weathering residue is relatively enriched in nickel, because some of the major elements of the rock have been leached out during weathering. These so-called nickel laterites are mined in a number of tropical countries for their nickel content. It is found that the ash of certain plant species known as hyperaccumulators, like *Hybanthus floribundus* from West Australia may contain up to 23% nickel, making it a valuable nickel bio-ore. Other well-known nickel accumulating plants are *Alyssum sp* and *Thlaspi sp* If, next to an olivine mine overlain by a nickel laterite, a thick bed of crushed laterite mixed with olivine powder is constructed, and planted with Ni-accumulating plants, several hundred US$ worth of nickel per hectare can be recovered annually. Thus, energy required for metallurgical nickel extraction is saved. At the same time, the weathering of the olivine captures $CO_{2.}$

# APPLICATION OF AN AUTOMATIC THERMAL DESORPTION - GAS CHROMATOGRAPHY FOR ANALYSIS OF POLYCYCLIC AROMATIC HYDROCARBONS IN SOILS

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A preliminary investigation to determine the Polycyclic Aromatic Hydrocarbons (PAHs) concentration in soils by an automatic thermal desorption-gas chromatography for surface geochemical prospecting of hydrocarbons was carried out. Thermal Desorption is an automated and sensitive alternative technique to traditional solvent extraction which has the drawbacks of using large amounts of organic solvents and long extraction times. This technique has the advantage of allowing the analysis of the samples without any pretreatment consequently reducing the organic solvent consumption, time of analysis and the risk of analyte loss or sample contamination. The Perkin Elmer TurboMatrix 150 Automated Thermal Desorber coupled to Perkin Elmer Clarus 500 Gas Chromatograph is used for the desorption of analytes. The paper demonstrates the methodology and experimental results obtained on the certified PAH standards and soil samples.

# EVALUATION OF HYDROCARBON PROSPECTS IN PROTEROZOIC CUDDAPAH BASIN

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A surface geochemical survey has been carried out in the Cuddapah basin to evaluate hydrocarbon prospects of the area. The light gaseous hydrocarbon concentration of 121 soil samples collected from a depth of 2-3 mts were determined by acid desorption technique using Gas Chromatograph equipped with Flame ionization detector. The concentrations (in ppb) of light gaseous hydrocarbons vary from 2-386 for $CH_4$, 1-87 for $C_2H_6$ and 1-44 for $C_3H_8$. The cross plots between the components $C_1$-$C_2$, $C_2$-$C_3$, $C_1$-$C_3$ show a linear trend indicating that the gases are genetically related and are from a single source. The hydrocarbon ratio of $C_3/C_1*1000$ ranges from 60-500 and 20-60 and the carbon isotope ratio of $CH_4$ ranges from -36‰ to -25‰, thus presenting an evidence that the hydrocarbons are derived from thermogenic source. A few samples are enriched in $\delta^{13}C_1$ (> -25‰) which might be due to the bacterial oxidation of $CH_4$ or that the gases are derived from humic type source. This work confirms the presence of hydrocarbons in the basin possibly derived from a thermogenic source and based on its concentration distribution, the areas near Koilkuntla and Bethamcherla are worth visiting for future research and exploration.

## GEO-MICROBIAL STUDIES FOR HYDROCARBON EXPLORATION IN THE EASTERN PART OF GANGA BASIN INDIA

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Geo-microbial prospecting for hydrocarbons is an exploration method based on the seepage of light hydrocarbon gases and their utilization by hydrocarbon oxidizing bacteria. The detection of anomalous population of light hydrocarbon oxidizing bacteria in the surface soil or sediment, helps to evaluate the prospects for hydrocarbon exploration. The reconnaissance surface geochemical surveys can be used to guide the location and extent of subsequent seismic coverage. In the present study the Geo-microbial prospecting studies for hydrocarbon exploration in eastern part of Ganga Basin have been carried out in reconnaissance pattern to know the prospectivity of the area. The Propane oxidizing bacteria (POB) ranges from 0.1 x $10^2$ to 3.58 x $10^5$ cfu/gm. The bacterial concentration distribution maps show distinct anomalies of high concentration of Propane oxidizing bacteria in the studied area. An integrated and complementary microbial microseepage signature study can identify gaseous hydrocarbon microseepage, which occurs directly above charged oil and gas reservoirs in on/offshore region. The possibility of detecting of oil or gas fields using microbial method is emphasized by the fact that the bacterial count of hydrocarbon-oxidizing bacteria in soil or sediment samples is relatively low (compared with non- hydrocarbon-oxidizing bacterial groups). The bacterial count ranges between $10^3$ and $10^6$ cfu/g in soil receiving hydrocarbon micro-seepages, depending on the ecological conditions (Wagner et al., 2002). In the present study the propane oxidizing bacteria were found to be around $10^4$ to $10^5$ cfu/gm of soil sample. The Geo-microbial prospecting studies for hydrocarbon exploration in eastern part of Ganga Basin study area, appears to be positive prospects for hydrocarbon exploration.

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## CONTRIBUTION OF THE GEOCHEMISTRY IN HYDROCARBON EXPLORATION

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Geochemistry plays a critical role in hydrocarbon exploration in sedimentary basins. Geochemistry of hydrocarbons is used to determine effective source rock, classifying petroleum system and delineating the genesis of conventional and unconventional oil and gas. With reference to petroleum geochemistry, the dynamic process of petroleum accumulations can be traced, which helps determining the prospecting target areas and reducing the exploration risk. Characterization of hydrocarbon systems including classification of oil families and detailed oil/source rock correlation based on state-of-the-art analytical methods, including biomarkers, carbon isotope composition of individual compounds. Modeling of source rocks and their evolution through time are calibrated with thermal data and kerogen and correlated to thermal evolution of oil and gas. Several migration scenarios are modeled, considering variations in petrophysical properties, fault conductivities and evolution.

*Keywords* : Geochemistry, SGP, Hydrocarbon exploration, Geochemical surveys.

# AN INTEGRATED STUDY ON SURFACE GEOCHEMICAL INDICATORS FOR OIL AND GAS PROSPECTING IN JAMNAGAR AREA, SAURASHTRA BASIN

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The application of surface geochemistry in prioritizing the areas for hydrocarbon prospecting and in reduction of exploration risk and cost has made it a vital component of any exploratory programme. We present here a study from Jamnagar area of Saurashtra basin, Gujarat, in which four different geochemical tools – the adsorbed light gaseous hydrocarbons (methane through pentane), carbon isotopes, soil iodine content and total organic carbon have been employed to observe their efficacy in defining an area potential in terms of hydrocarbon reserves.

The Saurashtra basin, particularly the Jamnagar area, is believed to have hydrocarbon bearing Mesozoic sediments, as the conditions favouring the hydrocarbon generation and maturation, besides its preservation under the Deccan Basalts exist. However, not much published information about hydrocarbon in the basin is available. The results of this study present new data and parameters of evaluation and substantiation of earlier work done for the appraisal of hydrocarbon prospects in the Saurashtra. The geochemical investigations on soil samples showed high concentration of thermogenic hydrocarbon gases: Methane (C1) = 3 to 518 ppb and Ethane plus hydrocarbons ( $\Sigma C2+$ ) = 2 to 1128 ppb respectively; Elevated soil iodine levels (1.5 to 68.5 ppm) and a rich total organic content (~5%). It is observed that the different geochemical indicators share a good correlation among themselves and also with the available geological and geophysical details regarding hydrocarbon prospects in Saurashtra.

The reliability of surface geochemical prospecting in oil and gas exploration and the promising potential of Saurashtra basin as inferred from the study is presented in the paper.

# SESSION - VI

# HYDROCARBONS (CONTINUED)

# WHERE TO SEARCH FOR GAS HYDRATES AND OTHER HYDROCARBON DEPOSITS BELIEVING THAT THESE ARE OF ABIOGENIC ORIGIN?

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It is a popular belief that the hydrocarbons are formed by transformation of sedimentary organic material and therefore are usually associated with the sedimentary rocks. In this connection, the latest research findings provide evidences which suggest that this inference is rather debatable and further point to the 'abiogenic origin' of hydrocarbons. The abiogenic concept is well supported by the hydrocarbons those are associated with the hydrothermal deposits forming at deep-sea floor. It is well known that the methane of hydrothermal origin is deep mantle derived released during serpentinite catalysis and support the abiogenic origin. Recent field surveys conducted for the 'Gas Hydrate' exploration in the Indian waters showed its abundant presence only in Krishna-Godavari (KG) Basin. Interestingly these are highly localized deposits having small areal dimensions despite similarity with surrounding sedimentary formations. Incidentally, occurrence of these deposits coincides with a 'submerged volcano' bounded by 'deep seated faults'. This coexistence of Gas Hydrates with 'submerged volcano and faults' suggest that only the regions having appropriate mode of transport of gases from mantle to shallow sediments are most favorable locales for the exploration of the Gas Hydrates. Other evidences viz. drilling data showing absence of Gas Hydrates in the Arabian Sea (the Kerala-Konkan Basin) and its minor occurrences in other regions of the Bay of Bengal (Mahanadi Basin and the Andaman Sea) all indirectly support the above. The same is also argued in the case of 'oil and gas' deposits occurring at various locations. Hence, it is suggested that we need to change the exploration perception and look for other regions for valuable hydrocarbon deposits which remain rather neglected or unprioritized so far.

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# DISTRIBUTION OF TRACE AND RARE EARTH ELEMENTS IN CRUDE OILS OF UPPER ASSAM AREA OF ASSAM AND ASSAM ARAKAN BASIN

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Trace elements are minor constituents of virtually all crude oils. Trace elements in source rock and petroleum have been used as diagnostic elements in genetic studies, migration process and maturity studies. The most abundant trace elements are vanadium and nickel. Trace element abundances (or elemental ratios) have been used to correlate oil families and oil with source rocks. Recently, rare earth elements and their ratios have been used as a geochemical tool for oil-source correlation.

In the present study, 50 crude oils belonging to TS-1 to TS-6 and LBS pay sands of Lakwa, TS-2, 3, 5 and BMS pay sands of Geleki, BMS pay sand of Rudrasagar, Sylhet and Kopili pay sands of Borholla, and TS-4 pay sand of Demulgaon and Charali fields of Upper Assam basin were analyzed on ICP-MS for various trace and rare earth elements. It is observed that distribution of trace and rare earth elements in different fields and pay sands of Upper Assam basin varies widely. The abundance of $Ni^{60}$, $V^{51}$ and $Co^{59}$ in oils of Upper Assam is very low in comparison to oils of North Cambay basin.

The oils of Rudrasagar and Boroholla fields have lower concentration of trace and rare earth elements than oils of Lakwa and Geleki fields. The BMS oils of Geleki and Rudrasagar fields can be distinguished from Tipam & LBS oils of Lakwa and Tipam oils of Geleki fields on the basis of distribution of $Sc^{45}$, $V^{51}$, $Cr^{52}$, $Co^{59}$, $Ni^{60}$, $Dy^{161}$, $Tb^{159}$ and total rare earth elements and their ratios.

The distribution of rare earth elements such as $Dy^{161}$, $Er^{167}$, $Yb^{171}$, $Tb^{159}$, $Ho^{165}$ and $Lu^{175}$ among the oils of Lakwa field reveals that oils of TS-6 and LBS and BSST pay sands form one group of oils and oils of TS-2, TS-3, TS-4 and TS-5 pay sands form another group of oils.

The study reveals that trace elements and rare earth elements distribution in oils can be used as geochemical tool in conjunction with other geochemical parameters for classification of oil families.

## MOLECULAR LEVEL CHARACTERISATION OF OILS TO ASSESS GENETIC RELATIONSHIPS IN TAPTI DAMAN BLOCK OF WESTERN OFFSHORE BASIN, INDIA

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Tapti Daman block is located in the north eastern part of Western Offshore Basin in India. Hydrocarbons have mainly been found in late-Oligocene (Daman) and in early-Oligocene (Mahuva) reservoirs. Oils were taken from C-1, C-2, C-23, C-39, B-9 and B-12 structures for molecular level characterization and genetic correlation. Most oils are characterized by high API gravity (>40°), low asphaltene (<1%) and wide ranges of pour point (0-36°).

Two groups of oils are clearly distinguishable by molecular level studies. These indicate that oils in Tapti-Daman area have been generated from two different sources i.e. H5-H5A sequence comprises of fluvio-deltaic shale/carbonaceous shale facies with thin interbeded coal layers indicating higher plant input and H4-H5 sequence, dominantly terrestrial with some marine input. Most of the oils have been generated by the fluvio-deltaic shale and coal whereas some oils are generated by the marine shale. One group has oils having high concentration of oleanane and low ratios of C29/C30 hopane and C35S/C34S hopane (<0.7), and are predominately derived from terrestrial organic matter. The other group having oils with low oleanane and high values of hopane ratios (>0.9) and are predominately derived from marine organic matter. Both groups are present in Daman and Mahuva reservoirs without any discrimination.

The maturity levels as revealed by isomerization reactions of hopane, sterane and aromatic biomarkers indicate similar moderate maturity. Oils from wells BL,BM,BB and BC are generated from carbonaceous source, probably thick organically rich layer of limestones.

The study will help to generate comprehensive knowledge on oil-oil correlation aspects in the studied area to give further insight and may help in future exploration.

## GEOCHEMICAL EXPLORATION FOR METHANE GAS HYDRATE

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Depleting conventional hydrocarbon reserves and increasing demand for energy have compelled us to think of unconventional sources of hydrocarbon to meet the requirement. Methane gas hydrate is one such hydrocarbon source. In an ideally saturated hydrate, the volumetric ratio of methane and water in methane hydrate is ~164:1. In other words dissociation of $1m^3$ of solid methane hydrate will produce $164m^3$ of methane gas and 1m$^3$ of pure water. Gas hydrates are crystalline molecular complexes formed from mixtures of water and suitably sized gas molecules. Gas hydrates are clathrates (cage) of water molecules with a guest gas molecule inside. Natural gas hydrates form as solid, icy compounds under a range of low temperature and high pressure conditions. In the natural environment, hydrates may be found in the sediments of the continental margins and the subsurface of Arctic permafrost regions. Estimated global reserve of methane in hydrated form range from 931 to 4655 trillion cubic m, which is significantly higher than conventional hydrocarbon reserves. Geochemical exploration for methane hydrate involves measurement of concentrations and isotopic ratios of various components in the fluid (gas and liquid) phases. Porewaters in the sediment core samples are extracted by hydraulic press and split into various aliquots for measurement of sulfate, sulfide, chloride and total alkalinity. Sub-sampling for gases are carried out either directly from gas pockets in sediments using vacutainers or sediments sub-samples are stored in crimped bottles with head space. Concentrations of lighter hydrocarbons (C1 to C4) are measured on board/ land by gas chromatograph. Concentration ratios (C1/C2+C3), $\delta^{13}C_{CH4}$ and δD values are used to interpret the source (biogenic, thermogenic or mixed) of hydrocarbon gases. Bacterial/ Archaeal mediated reactions of advecting methane with pore water sulfate ion results in sulfate reduction via anaerobic methane oxidation (AMO). The AMO zone is characterized by sharp rise in sulfide and total alkalinity. Methane concentration increases markedly below the sulfate methane transition zone. Chloride concentration is an important tool to decipher the amount of hydrate thawed during coring and extraction at non-seabed conditions. Thawing of hydrate releases fresh water which dilutes the chloride concentrations in the pore waters relative to seawater concentrations. On the contrary hydrate crystallization releases salt and enhances the chloride concentrations (roof top effect). Thus the chloride balance can be effectively used to calculate the hydrate saturation in the sediment core. δD of pore water can also be used along with chloride anomaly to calculate hydrate saturation.

## GEOBOTANICAL AND BIOGEOCHEMICAL INVESTIGATION OF CHROMITE BEARING AREAS OF NUGGIHALLI SCHIST BELT, KARNATAKA, INDIA

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Most plant species which grow in mineralized areas tend to accumulate metals, relatively in excess proportion than in non-mineralized areas. These higher levels of metals normally correspond to the higher concentration in the underlying soil and / or weathered substratum. This direct relation (unless affected) serves as a vital clue in biogeochemical prospecting for locating concealed mineralization. Thus, generating precise trace element data for different geobotanical and the corresponding soil samples and integrating them would be more useful in biogeochemical exploration for mineral deposits. The present paper brings out the metal concentration in different plant species and their underlying substratum in the selected chromite mineralized areas of Nuggihalli schist belt, besides a cursory geobotanical study. Nuggihalli schist belt - one of the ultramafic rich ancient (~3000 Ma) supracrustal belts in the Western Dharwar craton is chiefly constituted by ultrabasic rocks like dunite, pyroxenite serpentinite, gabbro and anorthosite. The chromite ores occur as lensoid bodies and pods which are discontinous, but occur all along the schist belt. The ore bodies are hosted in serpentinised ultramafic lithlogies. These ores have been mined both by underground and open pit methods. Nuggihalli schist belt expresses itself as an undulating, moderately elevated terrain at an altitude of 930 m above MSL. The soil cover is shallow (1-2 feet), generally coarse textured, greenish grey in colour, sandy with a mottled appearance, which is common in “serpentine’ soils which are produced by the weathering of ultramafic rocks. Natural vegetation is mostly restricted to more elevated areas. The vegetation is generally poor, and is of open, deciduous and scrubby type. Most part of the Nuggihalli schist belt shows poor/stunted vegetation which reflects the strong ‘serpentine’ nature of soil. The vegetation is dominated by shrubs and herbs. Four prominent mineralized areas viz., Byrapura, Tagadur, Jambur and Pennasamudra in the Nuggihalli belt have been selected with the objectives of (1) to study the possible morphological changes in the plant species growing in the soils of the chromite mineralised areas, (2) to determine the metal accumulation in the sampled species of plants, (3) to relate the composition of the soil to the metal concentration in the plant and their physiographic features and (4) to explore the possibility of recognizing local plant communities as indicator plants.

Before sampling of geobotanical species, a cursory reconnaissance field survey of different plant communities in the belt, especially around chromite bearing areas was carried out. The common endemic herb and shrub species with fair amount of density and homogeneity were selected for geobotanical and biogeochemical studies. The herb species included ***Hyuptis suaveolens, Chromolaena odorata, Sopubia delphiniifolia, Vicoa indica, Tephroisa purpurea, Leucas ciliata, Sida spinosa, Ocimum canum, Waltheria indica***, *and* ***Lapidagathis crisata*** in decreasing order of abundance, and shrubs ***Dodonae viscosa, Pavetta indica , Crotoloaria umbellata, Tecoma stans and Fern*** . However, from the point of density, Dodoneae is the most dominant species among both herbs and shrubs, and fern the least dominant species. All the above species of herbs and shrubs have been biogeochemically studied. The metals determined are Cr, Ni, Co, V, Fe, Mn, Cu, Zn, Mo, As and Se. High Cr content (> 400 ppm ) is noticed in all the analysed species of ***Dodonae viscosa***, except for one sample from the mineralized area of Pennasamudra (284.8 ppm). Significantly, Ni and Co are in very small concentration (4-37 ppm and 33-45 ppm respectively), though higher concentrations are expected in 'serpentine soils'. In ***Chromlaena ordarata*** Cr content ranges from 305.594 ppm, the highest in ore dump area of Jambur and relatively lesser value is obtained for the sample which is closed to mineralized area. Cu, Ni, Co, Zn, Mn, and As have concentrations in close ranges. V shows higher accumulation (than background) in the range of 166-319 ppm. ***Hyptis suaveolens*** reflect on the toxic nature of chromiferous substratum in the mine dumps. Chromite accumulation (399.6-651.8) is higher both in the plants of mineralized and dump area. No significant variation could be inferred from the species growing in mineralized and mine dump area. Fairly good and comparable values of Cr (169.2-180.6 ppm) Mo(105.6 - 411.2ppm) and V (133.2-203.8ppm) are concentrated in ***Hyptis suaveolens.*** Ni, Co, Zn, Mn, As are in smaller concentration but more or less in the same range. The Fe content is very high (925 ppm) in one sample from Byrapur. Highly variable valuables of Se have been detected for ***Hyptis suaveolens*** growing in the mineralized area of Byrapur (670 ppm) to that of Tagadur (378 ppm). However, another sample from Byrapur has yielded 16 ppm. Higher V content in response to higher Cr is also noticed with sampled species. ***Pavetta indica*** is observed mainly in Tagadur and Byrapur areas especially in zones where titaniferous magnetite are localized. One sample from the mineralized area of Tagadur and another from mine dump area have been analyzed for trace element concentration. The analysis indicates that Cr accumulation is high in both the samples (497-559 ppm). Moderate accumulation of Cu (218-237 ppm); and low Ni (3-8 ppm), Co (36-38 ppm), and Zn (1-3 ppm) are observed. Moderate to high accumulation of V (257-307 ppm), Se (293-380 ppm) and Mo (325-414 ppm) are also observed. ***Tephrosia pupurea*** is a perennial herb which shows high Cr concentration (477 and 479 ppm). Ni content is poor (11-24 ppm). V is also relatively high in content (404-2085 ppm. ***Sopubia delphinifolia*** shows higher Cr concentrations (659-569 ppm). Ni values are slightly higher when compared to other species except ***Chromolaena ordarata*** sample from Byrapura. Cu is in moderate concentration (174 to 201ppm). Co, Zn, As are in lower concentrations. Both the samples show higher V concentration (304-448 ppm). ***Fern*** species is mainly confined to old mine pits where high moist conditions prevail in Byrapur and Jambur. In both the areas they have accumulated high Cr which varies from 455-538 ppm. Ni, Co, Zn, Mn, Fe and Cu are almost in the background range. V is in high concentration (427-446 ppm). Wide variation is noticed in As concentration (4-94 ppm).

In conclusion, the serpentine soils of chromite bearing areas of Nuggihalli belt have supported poor vegetation growth. The shrub and herb dominated vegetation pattern is almost uniform in its density and distribution. The seven plant species investigated for their geobotanical and biogeochemical characteristic suggest that all of them reflect good accumulation of chromium in their apical parts. But the associated metals like Co, Ni, and V are not very well reflected in plants, when compared to their concentration in the soil over which the plants have grown. Wilting and poor growth of plant species are observed in Jambur mining area. Poor accumulation of some of the metals may also be due to slightly higher of pH soil.

# SESSION - VII
# LEGAL AND REGULATORY MEASURES

# CHANGING THE CLIMATE AND CLIMATE CHANGE

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The limitation of law is that it cannot regulate human greed and avarice. As such any legal regime sans the enlightened self interest of the dramatis personae is bound to be ineffective in the ultimate delivery system. The climate change is one such Gordian Knot.We do not have the luxury of pretending that climate change is a thing of the future. It is here and we have to fight it through the choices we make in everyday lives. Regarding Kyoto, Bali and Copenhagen what is required is not mutual fault finding but a holistic fact finding to make ourselves responsible and responsive to the posterity. What is more important is CHANGING THE CLIMATE in the political sphere.

# BRIEF HISTORY OF CHANGE AND THE REGULATORY FRAMEWORK FOR CLEAN ENERGY TECHNOLOGIES AND WHAT CAN BE DONE TO MITIGATE CLIMATE CHANGE?

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Brief History of change in our regulatory frame work for GHG reduction and the various Government of India initiatives like ‘Indian Electricity Act-2003’,‘Integrated Energy Policy-2006’, ‘National Action Plan on Climate Change 2008’, ‘The RDD and D Policy of MNRE-2008’. India’s commitment to develop Clean Energy Technologies and Carbon Trading both internal and external trading of Carbon Credits internationally.

# CARBON CAPTURE AND SEQUESTRATION FOR CLIMATE CHANGE—LEGAL PERSPECTIVES

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**“Climate Change is the defining human development issue of our generation” (UNDP)**

A major feature of the climate change is global warming which is a most pressing environmental threat to the planet earth. Fearful predictions about the consequences of global warming created an urge in the international community to respond to the problem of global warming. Having identified that anthropogenic Green Houser Gas effect is responsible for global warming , attempts are on to develop legal policies as well as scientific methods to curb GHG effect. $CO_2$ being the largest contributor amongst all the green house gases to the phenomenon of global warming, prime thrust of various strategies and policies is on the mitigation of $CO_2$.

Adoption of **Climate Change Convention in 1992** during the Earth Summit is the beginning of global policy. Adoption of **Kyoto Protocol in 1997** which actually came into force from 2005 for specifying the specific legal commitments relating to emission reduction is another forward step taken by the international community for tackling GHG effect. Flexible mechanisms introduced by Kyoto Protocol, Namely, Joint Implementation, Emission Trading and CDM have a practical import. However, so far as the actual result of the legal responses are concerned, one ends with a disappointing observation that nothing noteworthy has been achieved. Fulfillment of legal commitments remained far short of what actually is required. As the things stand today, without achieving much, the Kyoto Protocol is going to expire by 2012. Therefore, presently, the international community is grappling with the task of concluding a post Kyoto agreement. At

Bali meeting, it was agreed to start negotiations for future pact to be concluded by the end of 2009.It is largely understood that post Kyoto **(Kyoto 2**) negotiations will concentrate on the establishment of strengthening of global carbon market and on the importance of shifting focus from mitigation to adaptation.

The history of negotiations and state of implementation of any international agreement on an environmental issue shows that chances of its success depends on various factors like, economics, politics, science and society. Science and economics involved in the implementation of $CO_2$ mitigation targets are such that while they provide ways or means or incentives for implementation, nevertheless throw tough challenges for law to deal with.

One of the latest scientific solutions which supposedly takes better care of the dynamics between economic and environmental concerns involved in meeting $CO_2$ reduction targets is what is called as Carbon Capture and Sequestration (CCS) method. Sequestration is the removal of $CO_2$ either directly from the anthropogenic source or from atmosphere, and disposing it either permanently or for geologically significant periods. $CO_2$ is captured from anthropogenic sources such as fossil fuel energy systems and stored in different sinks like ocean, geologic formations and terrestrial sinks like plants or soils. CCS technology has the economic advantage in that it allows the continued use of low cost fossil till the development of better and efficient technologies.

Use of CCS however, brings to the forefront, various issues of legal regulation. Law being the prime medium of regulation of human conduct, has the social responsibility to respond to the anticipated problems and conflicts that are likely to arise in the use of CCS technology. Simultaneous working on the legal frame work needed for safe and non troublesome working of CCS technology goes a long way in lending support to the general goal of sustainable development and particular goal of $CO_2$ reduction which is promoted in global agreements on climate change, right from **CCC, 1992 to** possible **Kyoto 2**

This paper aims to discuss the possible problems of the use of CCS technology in legal context, the adequacy of the existing law to accommodate CCS and the possible directions in which the law may grow.

## CLIMATE CHANGE AND INDIA'S POLICY AND LEGISLATIVE INITIATIVES

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The latest report from the Intergovernmental Panel on Climate Change delivered a huge blow to global warming skeptics. Leading climate scientists are now 90 percent sure that human activity is heating up the planet.

Greenhouse gases in our atmosphere have increased since 1750 due to the consumption of fossil fuels, new forms of land use, and agriculture. While atmospheric pollution has had a cooling effect during the last centuries, the massive increase in greenhouse gases has lead to a rise of average temperatures by 0.74 degrees Celsius since 1901. Scientists are 90 percent sure that the last half of the 20th century has been the hottest period in the Northern Hemisphere since 500 years.

India is home to one of the fastest-growing economies in the world, and is currently the fourth-largest emitter of greenhouse gas (GHG) emissions. With nearly a quarter of its population living below the poverty line, the government is pursuing an ambitious development agenda.

It is an undeniable fact that developmental activities lead to the increase in the green house gases. Only economic growth will allow India to lift hundreds of millions of its citizens out of extreme poverty. But rapid Indian development also increases pressure on the global climate and unique ecosystems. How will India face this dilemma?

Growth in India is expected to cause energy consumption to quadruple from 2005 levels by the year 2030. If current trends continue, most of this energy will be produced from coal-fired power plants, making India one of the top-three greenhouse-gas-emitting countries by 2025.

Against this backdrop India's government is resisting international pressure to curb its greenhouse emissions. As a developing country India is exempt from mandatory caps on emissions. Developed countries, however, are demanding binding commitments from India. But with per capita emissions less than one tenth that of the average American, India says that it will not contemplate emissions cuts unless industrialized nations radically cut their emissions first.

At the same time, India has been aggressively pursuing several policy and legislative initiatives for combating climate change. While sustainable development remains the policy of India, the government has been focusing more on afforestation, energy efficiency, inclusion of forestry cover within the National Rural Employment Guarantee Act, Energy Conservation Building Code, CDM programs, and Impact Assessment of Climate Change. Besides these policy initiatives, India has also enacted legislations which directly or indirectly have a bearing on climate change.

The paper will examine and analyze these policy and legislative strategies and also applicable principles of customary law like the precautionary principle.

## ROLE OF "GREEN TAXES" FOR COMBATING CLIMATE CHANGE

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Government of India is likely to introduce Green Taxes in order to tackle the problem of Global Warming. The fourth IPCC Assessment Report (2007) states "most of the increases in globally averaged temperatures is very likely due to the observed increase in atmospheric carbon dioxide greenhouse gas concentration" and that "the primary source of the increase is fossil fuel use". It also says "continued greenhouse gas emissions, above current rates, would cause further warming and induce many changes in the global climate system in the 21st century that would very likely be larger than those experienced during the 20th century. This will have devastating consequences for the economic and social environment". Government need revenues to meet greenhouse gas emission reduction targets that they have committed to under the Kyoto Protocol. Pollution caused by automobile emissions poses a serious threat to the environment. On the principle that the polluter should pay, several Indian states have introduced `green tax' covering all classes of old motor vehicles. The aim in imposing a green tax is not only to sensitize people about the importance of flora and fauna but also to take measures to protect these from extinction. 'Green Tax' or 'Eco Tax' is a fiscal policy that introduces taxes intended to promote ecologically sustainable activities via economic incentives. This concept of green tax is aimed at discouraging high consumption of petroleum products may be in the offing. Several cities in India including Ahmedabad, Bangalore, Chennai, Hyderabad and Kolkata, have initiated to implement fiscal measures to address the problem of air pollution and congestion. The key focus of the fiscal measures are clean fuels and technologies including CNG, LPG and zero emissions technologies, disincentives for older vehicles, and creation of dedicated fund from taxes on polluting fuels to pay for pollution control efforts. The aim of this paper is to discuss about "green taxes" at national and international level in detail and finally ends with a conclusion with a hope that above taxes will act like a catalyst in reducing green house gases.

# SESSION - VIII
# EXPLORATION

## INTEGRATED EXPLORATION TECHNIQUES FOR CONCEALED TERRAINS

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Indian landmass is bounded by latitudes 07º 30’ 00” to 37º 06’ 00” N and longitudes 68º 30’ 00” to 97º 15’ 00” E, covering an area of 32,87,263 sq. km. However almost 59% of this land is occupied by the Himalayas in North, followed by Indoganga alluvium, Thar desert, Deccan Traps and coastal plains, thus, leaving much less area for hard rock mineral exploration. The Himalayas have not promised any rich metallic mineral potentials, except for small basemetal deposit of Askot in Uttrakhand, Rangpo in Sikkim and Ghonkhola in Bhutan. The thick pile of sand in Western Rajasthan and alluvials of Ganga, Jamuna and Brahmaputra in UP, Bihar, Bengal and Assam blanket possible presence of any mineral deposit under its cover. Similarly, the continental flood basalts of Deccan volcanism shield the metallotects from Southern extension of Rajasthan/ Gujarat to northern periphery of Karnataka, AP and MP States. We are yet to provide any insight to the mineral deposits below Deccan Traps. Therefore, the target areas for any metallic mineral exploration is restricted to northwestern, southern and eastern parts of Peninsular India.

The understanding of temporal distribution of mineral deposits has a major role to play for predictive metallogeny, since ores represent the fractionated products through endogenic and exogenic processes. Recognition of relationship among lithosphere, hydrosphere and biosphere will be a pathfinder to focus on new metallogenic deposits.

The target area for exploration involves stages of prospecting and exploration, followed by resource evaluation. The conventional methods of mineral exploration were mostly based on surface signatures like old workings, gossans and oxidized zones, which have been visited and revisited by field geologists several times. We are clueless for concealed deeper deposits with voluminous overburden, which may not reflect any direct surface signatures or more noise in geophysical signatures.

There is greater emphasis on regional geochemical and geophysical surveys to narrow down the areas for detailed exploration. The airborne and ground geophysical (EM, Magnetic, IP, SP, resistivity, mise-a-la-masse) are essential for deciphering subsurface configuration of ore bodies. Moreover with the availability of detailed geological maps on 1:50,000 scale, it is possible to prepare plate tectonic models, carryout remote sensing, prepare structural layout, geochemical surveys involving multi-element data and integrate to form broader format towards locating the concealed mineral deposits. With the entry of computer software, it is possible to simulate the model after assigning all the parameters. The geological, geophysical, structural, geochemical and remote sensing data, studied together, will enhance our information to delineate potential targets areas in concealed terrains.

## CRITICAL ELEMENT RATIO MAPS OF GRANITIC TERRAINS FOR EXPLORATION OF ATOMIC MINERALS

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This paper has five objectives: First, to propose a new type of geochemical map, named the ‘Critical Element Ratio Map’ (CERM), involving K/Rb, Ba/Rb, and Rb/Sr ratios, to aid exploration programmes for atomic minerals in granitic terrains. Second, to suggest wavelength-dispersive x-ray fluorescence spectrometry (WDXRFS) as the simplest, accurate, precise, and rapid analytical technique for determining K, Rb, Sr, and Ba in samples of granitic rocks. Third, to detail the procedure for determining K, Rb, Sr, and Ba in granitic rock samples by WDXRFS. Fourth, to suggest that, in addition to ore deposits of uranium, thorium, lithium, beryllium, niobium, and tantalum, critical element ratio maps can also be used to discover ore deposits of tin, tungsten, cesium, yttrium, and the rare-earth elements in granitic terrains. And fifth, to outline the methodology for preparing ‘Critical Element Ratio Maps’ of granitic terrains.

Granitic rocks formed from highly evolved melts are favourable for hosting ore deposits of uranium, thorium, lithium, beryllium, niobium, tantalum, tin, tungsten, cesium, yttrium, and the rare-earth elements. The characteristic geochemical features of this type of granite are very low K/Rb and Ba/Rb ratios and high Rb/Sr ratios.

The ‘average’ high-calcium granite (tonalites, granodiorites, and leucogranodiorites) has 25, 200 ppm K, 110 ppm Rb, 440 ppm Sr, and 840 ppm Ba, with a K/Rb ratio of 229, Ba/Rb ratio of 7.64, and Rb/Sr ratio of 0.25. The ‘average’ low-calcium granite (adamellites, granites, leucogranites, and alaskites) has 42,000 ppm K, 170 ppm Rb, 100 ppm Sr, and 420 ppm Ba, with a K/Rb ratio of 247, Ba/Rb ratio of 2.47, and Rb/Sr ratio of 1.7. In sharp contrast, granitic rocks formed from highly evolved melts will have a K/Rb ratio of less than 100, Ba/Rb ratio of less than 0.25, and an Rb/Sr ratio of more than 5.

The procedure for determining K, Rb, Sr, and Ba in granitic rocks by WDXRFS is as follows: Undiluted, plain, pressed, powder-pellets of 41 mm diameter prepared from 1-g powders (300 mesh) of granitic rocks, and identical powder-pellets of international granitic rock standards, are irradiated in a WDXRF spectrometer under the following instrumental conditions using a silver x-ray tube:

| S. No. | Z | Radiation | kV | mA | Analysing Crystal | Path | Collimation (µm) | Detector | Peak 2è $(^{0})$ | Background 2è$(^{0})$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | (1) | (2) |
| 1 | 19 | KK$_{\text{á}}$ | 40 | 20 | EDDT | Vacuum | 550 | GFPC | 50.29 | - | - |
| 2 | 37 | RbK$_{\text{á}}$ | 70 | 14 | LiF220 | Air | 150 | SC | 37.99 | 37.64 | 38.94 |
| 3 | 38 | SrK$_{\text{á}}$ | 70 | 14 | LiF220 | Air | 150 | SC | 35.85 | 35.40 | 36.95 |
| 4 | 56 | BaK$_{\text{á}}$ | 100 | 10 | LiF220 | Air | 150 | SC | 15.60 | 15.40 | 16.00 |

Counting: Fixed time. Three readings of 20s each for peak, involving a total counting time of 60s per powder-pellet, for KK$_{\text{á}}$, and three readings of 20s each for peak, background-1, and background-2, involving a total counting time of 180s per powder-pellet, for RbK$_{\text{á}}$, SrK$_{\text{á}}$, and BaK$_{\text{á}}$.

GFPC = Gas-flow proportional counter using P-10 gas (90% argon and 10% methane).

SC = Scintillation counter.

Calibrations relating the peak count rates of KK$_{\alpha}$ and the background-corrected net count rates of RbK$_{\alpha}$, SrK$_{\alpha}$, and BaK$_{\alpha}$ to the K, Rb, Sr, and Ba concentrations in the analytical standards, are derived by least-squares linear regression analysis. The resultant regression equations of the form, $y = a + bx$, where $y$ = counts per second of the characteristic radiations, $a$ = intercept, $b$ = slope, and $x$ = the concentrations of the respective elements, are used to compute the concentrations of the elements in the samples, for which values of $y$ are determined experimentally.

The accuracy of the procedure suggested is excellent (within 0.4% for K, within 2.1% for Rb, within 3.4% for Sr, and within 0.7% for Ba). The precision is also excellent (within 1.9% for K, within 0.8% for Rb and Sr, and within 0.7% for Ba). The lower limits of detection for the three trace-elements are: Rb = 3 ppm, Sr = 3 ppm, and Ba = 31 ppm.

The time taken for determining K, Rb, Sr, and Ba in a batch of twentyfour granitic rock samples, for a replication of four analyses per sample, by one operator, using a manual wavelength-dispersive x-ray fluorescence spectrometer, is only twelve hours.

The granitic terrains of Peninsular and Extra-Peninsular India should be systematically sampled, and fresh, unweathered samples collected for determining their K, Rb, Sr, and Ba contents by WDXRFS. Although it is desirable to undertake the sampling in a 200 m x 200 m grid, this is not always possible in practice. Therefore, the sampling should be confined to the available fresh and unweathered granitic outcrops. The K/Rb, Ba/Rb, and Rb/Sr ratios of the samples should be fed into a computer for generating 'Critical Element Ratio Maps' showing granitic areas characterised by anomalously low K/Rb and Ba/Rb ratios and high Rb/Sr ratios. These granites and the pegmatite bodies genetically related to them should be selected as first-order targets for exploring ore deposits of uranium, thorium, lithium, beryllium, niobium, tantalum, tin, tungsten, cesium, yttrium, and the rare-earth elements.

## A COMPARATIVE STUDY OF DIFFERENT EXTRACTANTS FOR THE DETERMINATION OF ANTIMONY IN AN ACCIDENTALLY POLLUTED SOIL

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Antimony is an easily dispersed element with toxicity to all organisms. Relatively high levels of antimony (~ 106 mg/kg) had been found in aqua regia soil extract of an accidentally polluted soil from south of Spain. To assess the available and leachable portions of antimony in the polluted soil, single and sequential extraction procedures have been utilized. Furthermore, X-ray diffraction and scanning electron microscopic studies have also been used to find out the mineral phases. The amount of antimony extracted by the extracting agents in comparison to aqua regia, as well as the different phase associations are discussed.

*Keywords* : Antimony, Single extraction, Sequential extraction, Accidentally polluted soil.

## THE DISPOSITION OF BANDED IRON FORMATION OF BAILADILA RANGE, SOUTH BASTAR DANTEWADA DISTRICT, CHHATTISGARH: ITS IMPLICATIONS ON EXPLORATION

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NMDC has conducted detailed exploration in most of the deposits in Bailadila Range and is presently exploiting Deposit Nos. 5, 10, 11 and 14. It is also trying to develop Bailadila Deposit No. 13. Bailadila Range which hosts the richest iron ore deposits in the country has fourteen deposits and the total reserve of all the deposits in this range is approximately 1400 MT. The iron ore deposits of Bailadila Range occur along two N-S trending synclinal ridges separated by a valley. From the outcrop pattern of the litho units of Bailadila Iron Ore Group it is inferred that the enriched pockets/iron ore deposits associated with Banded Iron Formations (BIF's) are mostly canoe shaped and these are in the linear belts of BIF which are bifurcating in nature. The iron ore deposits present in the BIF's of the eastern limb are wider and shallower compared to the iron ore deposits of the western limb. This could be due to the nature of synclines, which is open in eastern limb and tighter in the Western limb. From the outcrop pattern and structural data of the lithounits of Bailadila Group it is also observed that the enriched ore within the BIF are concentrated in the swelled portions of the synclinal depressions of the BIF's. The southern tips of the eastern and western limbs of the BIF's are totally eroded because of which the older formations of the stratigraphic sequence are totally exposed. Bifurcation of the anticline and syncline is observed towards the south. The synclinal overturned folding in the south of Bailadila Range and the outcrop pattern show concave towards south which resulted in the

enrichment of iron ore in Bailadila Iron ore Deposit No. 13. It could be concluded from the fold pattern that there could be some more iron ore deposits further to the south of Bailadila Iron Ore Deposit No.13 and 14. From the outcrop pattern and structural data of the lithounits of Bailadila Group it is opined that the enriched ore within the BIF's are concentrated in the swelled portions of the synclinal depressions of the BIF's. Similar swelled portions of synclinal depressions may be taken up as a model for targeting for iron ore within BIF's.

## MINERALIZATION POTENTIAL OF THE GRANITES FROM NAKORA RING COMPLEX, BARMER DISTRICT, W. RAJASTHAN, INDIA : A GEOCHEMICAL PERSPECTIVE

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The rocks of Nakora Ring Complex (NRC) belong to the Neoproterozic Malani Igneous Suite (MIS) and occur in the Trans Aravalli Block (TAB) of Peninsular India. NRC constitute three phases viz. i) Extrusive (mainly rhyolites with minor amount of initial basic flows), ii) Intrusive (mainly granites with less amount of gabbroids) and iii) Dyke (mainly of dolerite with few rhyolitic and micogranitic composition). They occur in the form of ring structures and radial dykes. The granites show intrusive relationship with rhyolite which exemplifies the volcanotectonic association of the NRC.

In NRC the granites are medium, pink/grey in colour, hard, compact and massive.They display hypidiomorphic, granophyric textures and they are hypersolvus as well as subsolvus. They consist of quartz, orthoclase, perthite, albite, arfvedsonite and riebeckite as essential minerals and zircon, sphene, magnetite and hematite as accessory minerals. Alkali feldspars show cloudy appearance and traversed by quartz veins. The cloudy appearance illustrates a post magmatic fluid interaction. The perthites are cloudy, patchy, incoherent and coarse due to feldspar fluid interaction.The presence of iron oxide or fluorine encrustation in Nakora granites indicates involvement of hydrothermal process. The fluorine influences the enrichment of the HFS elements in the granitic rocks.

Geochemically the granites of NRC are of A-type and formed in anorogenic tectonic setting. The granites also display high content of metals viz. Ni, Cu, Zn, Rb, Sr, Zr, Th, U, La, Ce and Y. The progressive differentiation of magma supported by negative correlation of Rb against Sr which are suggesting the mineralization nature of the granite. High Rb/Sr, Ba/Rb, Zr/Rb, Zr/Nb and low K/Rb, Ba/Rb, Zr/Y, $TiO_2$/Ta Th/U values indicate that these granites have undergone post-magmatic hydrothermal alteration process and resulted into various types of mineralization. In Rb-Sr-Ba diagram they plot in the field of mineralized granites. In the Zr-Rb diagram, the Nakora granites are plotted towards the field of Nb-Sn bearing granites. The enrichment of radioactive elements (U,Th,K) indicate them as high heat producing (HHP) granites. Average of nine granites (Type I) of NRC show U (4.93), Th (16.00), K (4.42), Th/U (3.04), Ur (21.77) and HGU (6.81) except one granite (Type II) (sample no. 167) which shows the high contents of U (19.38), Th (69.64), K (5.93), Th/U (3.59), Ur (66.06), HGU (25.30) and HP (10.63). Type II granites show high contents of RMRE including radioactive elements and subsolidus hydrothermal alteration processes.

Present data suggest that the granites of NRC are mineralized for rare metals, rare earth and radioactive metals.

# GEOCHEMICAL SYSTEMATICS OF SPINIFEX TEXTURED KOMATIITES FROM SIGEGUDDA GREENSTONE BELT, WESTERN DHARWAR CRATON, INDIA

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Sigegudda greenstone belt of western Dharwar craton (WDC) has excellent preservation of spinifex textured komatiites that are associated with komatiitic basalts, quartz pebble conglomerate, quartzites, dacites, shoshonites and leucitites. Like other greenstone belts of WDC, Sigegudda belt also starts with basement gneiss followed by QPC, quartzites, banded iron formations followed by island arc related volcanic rocks. It is observed that komatiites of this belt have been deposited as two flows. Upper and lower flows have a tectonic contact and shear zone in between them. Upper flows of komatiites have pyroxenes (opx) with talc, amphiboles, Mg rich chlorite and opaques (chromite). Lower flow has radiating tremolite-actinolite, relict olivine, pyroxenes (opx and cpx), quartz and opaques. Metabasalts have amphiboles, relict pyroxenes, plagioclase and opaques.

Upper and lower komatiites have similar $SiO_2$ (45-47 wt.%) but $TiO_2$ ( ~0.35 wt.%) and $Al_2O_3$ (6.7 – 9.6 wt.%) are lower in upper komatiitic flows than lower flows. Upper komatiites have consistently higher MgO (22 – 36 wt.%) than lower flows. CaO is also higher (5-11 wt.%) in upper flow than lower flow but $P_2O_5$ is lower than lower flow and komatiitic basalts. Ta, Zr, Th and U are lower in upper komatiites compared with lower komatiites and komatiitic basalts. Total REE is very low in upper komatiites and exhibit depleted REE patterns with LREE depletion, HREE enrichment and negative Eu anomalies. Few samples exhibit positive to negative Ce and negative Yb anomalies. Multielement variation figures display negative Nb, Hf and positive V anomalies. Lower komatiites have slightly higher $TiO_2$ (0.86 wt.%) but almost similar $TiO_2$ with komatiitic basalts (0.75 wt.%), similar to slightly lower MgO than upper flows but higher than komatiitic basalts. Cao is lower than upper flows (2-5 wt.%). $Na_2O$, $K_2O$ are similar in upper, lower and komatiitic basalts. Cr (1040 – 2863 ppm), Co (65 – 80 ppm), Ni ( (630 – 1150 ppm), Rb, Sr, Cs, Ba, Sc, V and Ta are all similar in all three varieties but Th and U are moderately enriched, Y is higher in lower komatiites and komatiitic basalts. Total REE is moderately high and exhibit flat REE patterns with $La/Sm_n$ = 0.85 – 1.53 and $Gd/Yb_n$ = 1.26-1.83 and exhibit small scale negative Eu anomalies and their multielement patterns display negative Nb and Ti anomalies. Associated komatiitic basalts have higher $SiO_2$, similar $TiO_2$ than lower komatiites, higher $TiO_2$, lower MgO than lower and upper komatiites. CaO is similar with lower komatiites. $Na_2O$, $K_2O$ and $P_2O_5$, Cr, Co, Ni, Rb, Sr, Cr, Ba, Sc and V are similar with both types of komatiites. Zr and Th are higher than lower and upper komatiites. Nb and Ta are similar with lower komatiites but in upper komatiites these elements show little abundance. Total REE is higher. Komatiitic basalts display moderately enriched, flat REE patterns with slight enrichment in LREE ($La/Sm_n$ = 0.92 – 1.67) and $Gd/Yb_n$ = 1.16 – 1.96) and slight positive Eu anomalies. Multielement patterns display negative Nb and Ti anomalies. Identification of distinctive associations based on stratigraphic relationships and geochemistry indicate the model of accretion of plume related convergent margin sequences in this greenstone belt of WDC.

# PYRITIFEROUS HORIZONS IN LOWER ARAVALLIS, PARSOLA AREA, UDAIPUR DISTRICT, RAJASTHAN, INDIA

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Parsola area, southern Rajasthan, India was studied for search of basemetal and gold mineralization. For the purpose the Barasarpatia block located southeast of Parsola was taken up for detailed study. The area comprises quartzite, phyllite, dolomitic marble and metabasic of the Delwara Group of the Palaeo-Proterozoic Aravalli Supergroup. A prominent ferruginous zone occurs almost continuously along the contact between phyllite and dolomitic marble. This rock sequence is underlain by granite gneiss and amphibolite of the Archaean Mangalwar Group on the eastern side. The phyllitic rock often displays shades of light grey to dark grey and black. These phyllite earlier considered to be carbonaceous have now been identified as manganese bearing without graphite/carbon content. The general attitude of the main lithologies of the block is NNW-SSE with steep dip towards southwest. The oxidized zone also trends in NNW-SSE direction and is conformable to the regional dip. The imprints of at least three generations of folding can be seen in the area. The first generation folds (F1) are rare and occur as rootless and hook shaped folds. The second generation mesoscopic folds have been seen in a few places. The regional pattern of the rock types of the area is governed by F2 folds. The folds (F2) show 42° to 60° plunge towards SSW or south. The third generations F3-fods are generally open warps on NE-SW axis with steep to vertical plunge. The western part of the block is highly fractured and sheared.

The analytical results of channel samples and random bed rock samples of ferruginous band in Barasarpatia block indicated anomalous values of Zn along with Pb, Ni, Co, Cd and Mn. The Au content varies from less than 10ppb to 345ppb. This zone shows 16.15-61.74% iron content.

Six boreholes were drilled in Barasarpatia area. The drilling data indicate the persistence of main ferruginous (oxidized) cum old working zone up to about 200m vertical depth from surface. The borehole data also indicate that the main oxidized zone shows higher values of Zn (0.38-0.61%), Ni (292-569ppm), Co (89-182ppm) and 0.07 to 0.94%Mn at deeper levels. The values of Au in this zone is generally very low, i.e. <10ppb. No sulphide zone was intersected in the boreholes corresponding to the main ferruginous/old working zone.

There is a thick (~ 100 m wide) sequence of phyllite on eastern (footwall) side of main ferruginous zone. This sequence shows several thin to thick (5-40m) pyritiferous zones with higher Zn (0.018-0.45%), Ni (50-397ppm), Pb (5ppm-0.41%) and Mn (102-3600ppm) values. The Au content varies from <5ppb to 18ppb. The quartzite which is exposed on the eastern side of phyllite is also pyritiferous/sulphidic. The dolomitic marble which occurs on western side of phyllite also shows pyrite disseminations.

The ferruginous zone exposed at surface appears to be developed as a result of shearing of pyritiferous phyllite horizon along the contact with dolomitic marble. The down dip extension of this zone is limited to about 200m depth as indicated by subsurface data. Notwithstanding the phyllites and quartzites sequence of the area hitherto unknown for basemetal mineralization have been identified as the potential targets for syngenetic type of sulphide mineralization. The pyrite/basemetal bearing phyllite/quartzite sequence shows a substantial strike continuity and hence may be explored for basemetal potential.

# SESSION - IX
# EXPLORATION (CONTINUED)

# PLATINUM GROUP ELEMENT (PGES) EXPLORATION STUDIES IN INDIA-CURRENT STATUS

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## Introduction

The platinum group elements (PGEs: Ru, Rh, Pd, Os, Ir, Pt) abundances in crustal rocks that have formed from silicate melts and magmatic volatile phases, are widely studied to identify the fundamental geochemical controls of their formation and distribution in Earth's crust and to understand the primary mantle derived magmatic processes as well as the secondary enrichment processes responsible for the formation of PGE mineralized zones in different geological and tectonic settings all over the world. PGEs are currently receiving world-wide attention as attractive exploration-targets because of their commercial value and extensive utility in high technology applications. Hence, the discovery of new PGE deposits/mineralized zones is of great economic importance for the country. PGE and Au generally occur at exceedingly low concentration levels (ng/g) in crustal rocks as they along with other highly siderophile elements were effectively and near quantitatively fractionated into the core and mantle leaving the crust strongly depleted, during the formation of the Earth. Orthomagmatic ores such as Ni-Cu-PGE sulfide ore deposits are formed from ultramafic-mafic magmas due to high temperature fractional crystallization processes and directly linked to the evolution of parent magmas (Mondal, 2008). So far, in PGE front not much progress has been made in India, mainly due to the non-availability of sufficient number of laboratories capable of precise estimation of PGE at their natural abundance levels in different lithologies. But due to their growing demand and applications, PGE exploration has gained momentum in recent years (Balaram, 2006).

## Potential areas for PGE mineralization in India

PGE mineralization occurs in layered igneous complexes, ultramafic rocks komatiite in greenstone belt and ophiolite sequences. The occurrences of PGE has been reported in the last three decades only from the plutonic to hypabyssal magmatic intrusions of Archaean - Early Proterozoic age, mostly emplaced into the cratonic areas to the south of the ENE-WSW trending Son-Narmada Lineament. Some of the layered ultramafic complexes ± chromite have indicated moderate to high anomalous PGE values. Such prominent occurrences are reported from Sukinda and Baula – Nausahi areas of Orissa in Singhbhum Craton (Mondal and Baidya, 1997, Auge et al., 2002), Sittampundi area of Tamil Nadu in Southern Granulite Belt (Sathyanarayanan et al., 2007) and Hanumalapura area of Karnataka in Dharwar Craton (Devaraju et al., 2007). Naldrett (2008) is of the opinion that intrusions of the Khetri Lineaments, Sittampundi Anorthosite Complex, Komatiites of Dharwar Craton and the Nuasahi-Sukinda Igneous Complex of Singhbhum Craton would offer scope for continuing research on magmatic Ni-Cu-PGE deposits in India.

## PGE Exploration Studies by NGRI

The Bundelkhand massif in the northern part of the Indian shield has Mid- Archaean gneissic nuclei in the Late Archaean to Palaeo-Proterozoic granites. A number of outcrops of metamorphosed mafic and ultramafic rocks around Madawara, Ikauna, Girar and Karitoram areas in Lalitpur district, Uttar Pradesh, have been encountered at the contact with high-grade metamorphites of Bundelkhand Gneissic Complex and the lower part of banded-magnetite-quartzite of the Bunldelkhand metasedimentary and metavolcanics. Geochemically, these rocks are characterized by high MgO, Ni and Cr values which have been classified into komatiites and basaltic komatiites. Earlier studies in Ikuana area have indicated Pt and Pd in serpentinized peridotites of upto 1.71 µg/g and 2.02 µg/g respectively (Farooqui and Singh, 2006). An attempt has been made to generate extensive geochemical data on these rocks to have a comprehensive understanding of the major, minor, trace, REE and PGE geochemistry including the petrology of the peridotites, pyroxenites (partially altered to serpentinized and talc-actinolite schist), coarse-medium grained gabbro and basic granulites, in order to fill the existing gaps in our understanding in the light of PGE potential of these rocks (Singh et al., 2009)

### PGE Potential in Ophiolite Complexes

Recent advances have widened the range of known settings for PGE mineralization in ophiolite complexes. Chromitites are the important hosts of PGE in ophiolitic complexes around the world. Traditionally, ancient oceanic crust represented by ophiolite complexes was thought to be enriched only in Os, Ir and Ru. More recently, significant concentrations of Pt and Pd have been observed in several ophiolite complexes, generally in association with sulfides and disseminated layers of chromite in thick dunite-rich sequences (Orberger et al., 1988). The Naga-Manipur Hills-ophiolite belt consists of considerable extent of mafic-ultramafic rock assemblages such as gabbros and nodular serpentinite dunite often in association with chromite mineralisation. Lack of PGE and other trace element data has contributed to the poor understanding of the formation of this ophiolite suite of rocks. A few studies were attempted to document abundance levels of PGE and Au, their petrogenesis, distribution and fractionation trends, and significance of metamorphic processes and economic implication of ultramafic rocks in this belt. (Srikanth et al., 2006, Balaram et al., 2004, Krishnakanth Singh, 2008).

### Occurances of PGE in Organic Matter-Rich Sedimentary and Metasedimentary Rocks

Black shale-hosted PGE deposits have recently become promising sources of PGE and many other metals in some parts of the world. Recently, many unconventional PGE accumulations and new data on PGE distribution have been reported from marine black shales of China, Canada, USA, Czech Republic, Finland, Poland and Russia. Submarine volcanogenic-hydrothermal processes are thought to be the principle contributors of these metals deposited in the vicinity of volcanic centers (Pasava, 1993). The evolution of numerous local sedimentary basins, developed within the shallow shelf, and the introduction of warm metal-bearing fluids during deposition or diagenesis, along with the important role played by abundant organisms, could have been the major mechanisms for the formation of these deposits (Murowchick et al., 1992). Their chondrite-normalized PGE+Au patterns show a relatively strong enrichment in Os and a depletion of Ir and Ru. Similar trends have been noticed in the black shales collected from the Mangampeta barite horizons in the Cuddapah Sedimentary Basin. Similar studies are in progress on the black shales of Chitradurga and Sandur Schist belts and the metaliferous black shales from Mussorie section in Garhwal Himalaya.

### PGE Potential of Deccan Volcanic Province

Large Igneous Provinces (LIP) related to mantle plumes such as Siberia and Emeishan are found to be Ni-Cu-PGE bearing. LIPs (including oceanic plateaus) around the world have been studied quite extensively for understanding their genesis as well as for prospecting magmatic Ni-Cu-PGE sulfide ore deposits. Plume centre regions are likely the regions of PGE ore deposits, and can be determined using giant radiating dyke swarms and other criteria. In this context, continental flood basalts and associated ultramafic sills of Deccan Volcanic Province (DVP) are potential sources for PGE. Anomalous concentrations of ΣPGE (> 50 ng/g) were found in the picritic basalts in Igatpuri area (~185 km NE of Mumbai) in the western lava pile of DVP. Concentrations of Ni (~400 µg/g), Cr (~700 µg/g) and MgO (upto 15%) suggest a favorable environment for a possible PGE mineralisation in picritic basalts of Igatpuri. The Linga ultramafic sill (thickest sill-200m) emplaced in Deccan basalts of Mandla-Jabalpur areas will be taken up for further studies.

### PGE in Marine Sediments

The Fe-Mn rich seamount crusts exhibit enrichment of metals over seawater composition by several orders. The most dominant metals are the transition group of elements comprising Mn, Fe, Co, Ni, Cu, V, Pb, and Zn. The second group of elements that are enriched is the REE followed by PGE. Recent studies (Banakar et al., 2007) have confirmed the presence of PGE (especially Pt upto 1µg/g) in ferromanganese crusts from the Afanasy-Nikitin Seamount (ANS) in the equatorial Indian Ocean. Although considerable work has been done on the Fe-Mn crusts of the world oceans, the studies on Indian Ocean Fe-Mn crusts are limited. Under the Ministry of Earth Sciences, The National Geophysical Research Institute, Hyderabad, National Institute of Oceanography, Goa and National Centre for Antarctic Research, Goa have undertaken a collaborative project to examine the PGE distribution and physicochemical conditions of PGE incorporation in seamount cobalt-crusts under variable oceanic environment. The study not only aims to determine the enrichment of PGE in general and Pt (platinum) in particular, but also proposes to characterize the mobility patterns of these elements. The knowledge of Pt-enrichment in these deposits is necessary as this metal adds to the basic commercial value of the deposits.

## PGE Reference Material

Any interpretation of PGE geochemical data requires bias-free concentration values that are not affected by systematic errors (Balaram, 2008). In this context, reference materials are used to calibrate the instruments, to compare the results of different laboratories and to validate the analytical method for the intended purpose. Since PGE concentrations are in ng/g range in many samples normally studied, matrix matched reference materials are required to improve the data quality and to minimize the interference effects and thereby the measurement uncertainty. An attempt has been made to prepare a low abundance PGE reference material from indigenous source to cater to the analytical requirements of exploration studies on PGE in India and to fill the gap between high and low abundance PGE reference materials, which are available from a few international agencies. The geochemical reference material for PGE was prepared from Bangur Gabbro, which forms an oblong intrusion of gabbro-norite (~3.1 Ga), cutting the gabbro-anorthosite unit and the southern part of the ultramafic unit in Baula-Nuasahi Complex, Orissa. About 300 kg of the sample were selectively collected from an underground mine, at a depth of ~ 30 m bgl. Several sample aliquots were analyzed for their major, minor, trace elements including REE and PGE and the sample homogeneity has been established. The samples show enrichment of PGE (ΣPGE 0.89- 4.11 µg/g) and show fractionation trends. It is proposed to conduct an International Round-Robin Test in order to arrive at reference values for Ru, Rh, Pd, Os, Ir, Pt with minimal uncertainty and to validate the method, by circulating the powdered sample to National and International Geochemical Laboratories.

## Conclusions

For identifying economically viable deposits and their mining, detailed geological, petrological and geochemical studies are essential on a massive scale in potential areas. Recent studies show that there is a tremendous potential for PGE-mineralization in mafic-ultramafic and ophiolite complexes, and the fine grained sediments such as sulfide bearing black shales, occurring in different parts of India. The analytical centers with capabilities for the precise estimation of PGE and also for the required mineralogical studies are being established in different parts of the country. Only a few R&D Earth Science organizations and a handful of Indian Scientists are involved in this very important and socially relevant endeavour. In view of the recent large increase in the prices of Ni and PGE, and because of their increased applications in high technology applications coupled with the current pace of industrialization in India, it is essential to intensify our research efforts on the topic of magmatic sulfide deposits. Only a consorted and integrated effort towards a conceptual understanding of the nature of the inter-relationship between the magmatic sulfides and their host rocks will facilitate the discovery of hidden Ni and PGE resources that surely occur within India.

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# ROLE OF MULTI-DISCIPLINARY SURVEYS IN DILINEATION OF TARGET AREAS FOR MINERAL EXPLORATION - A CASE STUDY FORM THE EASTERN MARGIN OF BASTAR CRATON, CENTRAL INDIA

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Ground evaluation of integrated data maps prepared by overlying of aeromagnetic, spectrometric (U, Th, K and total count), LANDSAT imagery, aerial photo interpreted maps along with geological, geomorphological and drainage analysis data on 1:50,000 scale was carried out covering an area of 3800 sq.km in parts of the eastern margin of Bastar Craton in Chhattisgarh State to know the disposition of different litho-units, in particular the mafic-ultramafic rocks vis-à-vis the various tectonic/structural elements with a view to delineate the significant areas of interest / target blocks for subsequent detailed evaluation and follow-up geochemical surveys for mineral exploration and in particular to locate the Kimberlites and related rocks of economic interest.

The Bastar Craton, Eastern Ghats Mobile Belt (EGMB) of late-Archaean to early-Proterzoic and sedimentary syneclises of middle-late-Proterozoic age form three distinct tectonic units in the area. The Bastar craton is flanked by Chhattisgarh basin in the north, Eastern Ghats Mobile Belt (EGMB) to the east, gneissic

complex in the south and west and Pranhita-Godavari Basin in the southwest. The Bastar craton comprises gneissic complex, greenstone belts and Bundeli granitoids of various generations and exhibit two distinct structural trends, the NNW-SSE to NW-SE and E-W trends. The abyssal fractures of this Cratonic area are manifested by the presence of mafic-ultramafic dyke swarms of varying mineralogical composition, trending mostly NW-SE and at places NE-SW. The high grade granulites of Eastern Ghats Mobile Belt (EGMB) contain, apart from the major khondalite-charnockite association, intrusive mafic-ultramafic rocks ranging in composition from dunite, pyroxinite, norite, gabbro, gabbroic anorthosite and anorthosite and alkaline complexes with N-S to NNE-SSW trend. The Bastar Craton-Eastern Ghats Mobile Belt (EGMB) boundary is marked by N-S trending ductile shear zone. The middle-late-Proterozoic sedimentary sequence unconformably overlies granite/granite-gneisses of Bastar craton and is named as Chhattisgarh Super group, Khariar Supergroup, Indravati Supergroup, Ampani Group and Singhora Group in different basins. These are block faulted sedimentary basins upheaved into broad syneclises. These rocks in general comprise of conglomerate, sandstone, shale, chert and limestone. The study area forms the eastern margin of Bastar Craton and the adjoining Chhattisgarh basin.

An exhaustive study of integrated multi-layer thematic data maps coupled with field evaluation of geological and structural elements, revealed that the prominent fracture lineaments have NW-SE, NE-SW and E-W trend in the area. Similarly, the magnetic breaks and linears also show NNW-SSE to NW-SE, NE-SW and E-W trends. Ground magnetic (V.F) surveys in selected places further substantiate the presence of basement ridges in the area. Field evidences indicates that of E-W and NW-SE trending magnetic breaks /linears correspond to NNW-SSE to NW-SE trending shear /fault zones with profuse development of epidote and quartz veins and augen gneiss structure in granites; the presence of a number of NW-SE trending dykes of varying mineralogical composition (ampbibolite/dolerite/gabbro/ pyroxenite) at several places. The spectrometric (U, Th, K and total count) data has helped in identification and delineation of various litho-units and different types of granite.

From a detailed study of these integrated maps, coupled with the field evaluation of geological and structural elements, kimberlites and related rocks are postulated to be at around intersections of E-W and NW-SE magnetic breaks/ linears and the corresponding lineaments. Many of these lineaments represent surface expressions of long abyssal fracture systems extending for hundreds of kilometers and all the trends cross-cut the area, underlain by late-Proterozoic cover sedimentary rocks. Most of these mafic–ultramafic dyke swarms appear to be syn/post-tectonic intrusives emplaced along NW-SE or NE-SW shears /fracture system in an extensional tectonic regime. Based on the filed observations and follow-up laboratory studies, viz. petrography, geochemistry of bed rock samples, heavy mineral data from stream sediment samples, seventeen priority blocks were delineated in the study area for further detailed exploration.

The results are well corroborated when compared with the various known kimberlite /lamproite fields of India and elsewhere. As many kimberlites appear to be related to the reactivation of major zones of weakness /linear features in lithosphere, the integration, interpretation and ground evaluation of multi-layer thematic data maps play a pivotal role in selection of target areas for detailed geochemical surveys in such areas to locate the pipe rocks to intensify the diamond exploration.

*Keywords* : Bastar Craton, Eastern Ghats Mobile Belt, Chhattisgarh Supergroup, Mafic-ultramafics, Kimberlites, Diamond.

## IMPACTS DUE TO LIMESTONE MINING ACTIVITIES ON LAND AND WATER RESOURCES IN AND AROUND SANKARNAGAR (THALAYUTHU), TIRUNELVELI DISTRICT, TAMILNADU, USING REMOTE SENSING AND GIS TECHNIQUES

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Thalayuthu area in Tirunelveli district of Tamilnadu in India is commonly known as Sankarnagar due to the location of Sankar Cement Plant, belongs to M/s. India Cements Ltd. The limestone produced are mainly supplied to the cement plant located at Sankarnagar, whereas the calcite and dolomitic limelstone is supplied to Burnt Lime (locally known as Cem) Units and other chemical industries in and around Tirunelveli district. Limestone being the basic raw material for the production of Clinker for Cement and for other lime based products such as Quick lime, burnt lime, etc., the limestone mining in Tirunelveli district is countinues process and dates back to 18th Century. Around 85 mining leases are worked in the district meant for production of limestone. The mining area in and around Sankarnagar remained the main suppliers of limestone and dolomite for more than 200 burnt lime units in and around Tirunelveli district. Sankarnagar in Tirunelveli district is a hot place. The highest temperatures around 37°C during April and with lower temperatures up to 19°C are recorded. The mean maximum and mean minimum are around 30 to 32°C to 22° to 25°C respectively, indicating that winter does not lower the temperature. Continues emission of $CO_2$ and heat from these lime based industries and lime dust from the crushing plants are causing further damage to the climate. The limestone mining areas in Sankarnagar are traversed by Thalayuthu Reserve Forest range, the environemtn adjacent to forest range is highly degraded due to the continuous limestone mining and stone crushing activities, causing destruction of the natural landscape, environment, geochemistry and the geomorphology. The study area is falling in the coordinates of 77° 33' 75'' to 77° 44' 56'' North latitude and 08° 55' 23'' to 08° 46' 35'' East longitude on Toposheet No.58H/9 of Survey of India, covering parts of Tirunelveli and Palayamkotai taluks. The available Remote Sensing Satellite Data as well as the Global Positioning System (GPS) is used for the mapping of Limestone Mining areas and the lime based industries. The study is made to delineate potential limestone and quarrying zones by integrating information extracted from Remote Sensing data and by processing through available GIS Software for the impact studies.

## REPORTING OF A RARE SECONDARY URANIUM MINERAL, LANTHINITE AT MYSEMGUTTA, ADILABAD DISTRICT, A.P.

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# EFFECTIVE UTILITY OF RADON EMANOMETRY IN URANIUM PROSPECTING - A FEW CASE STUDIES FROM DIFFERENT PARTS OF INDIA

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Among the various techniques being applied in radiometric prospecting, the only tool capable of penetrating to large depths in soil, is the method of **radon emanometry**. This technique is a well established method in uranium prospecting, particularly in tracing the extension of concealed ore bodies besides locating / deciphering fracture / fault zones that are associated with the ore body. Radon gas has the property of migrating to large distances from its source and can be transported by ground water movement because of migration. It is because of this inherent quality of diffusion and migration that radon emanometry finds vide application in radiometric prospecting. Effective use of radon in radiometric exploration stands predominant because of the simple fact that radon is a daughter product of Radium which in turn is a daughter of Uranium of the U-238 series. It is a gas with atomic number 86 and has three isotopes namely Radon-222 (radon), Radon-220 (thoron) and Radon-219 (actinon) of the Uranium, Thorium and Actinium series having 3.825 days, 54.5 seconds and 2.19 seconds as half lives respectively.Of all of them, Rn-222 and Rn-220 do play a vital role in discriminating, deciphering and delineating favorable structural controls of uraniferous and thoriferous horizons.

In the Atomic Minerals Directorate for Exploration and Research (AMD), radon emanometric studies are in vogue for the past four to five decades and extensively used in soil covered areas, to decipher structural controls like faults / fractures controlling mineralization and the anomalies serve as path finder for the concealed uranium mineralisation. A number of techniques like the Closed Circuit technique (CCT) and Solid State Nuclear Track Detection (SSNTD) are normally employed in various field areas to achieve the above objective.

In brief, the present article attempts to highlight the various techniques of radon emanometry being applied in AMD and the merits and limitations of each technique are discussed in detail. Successful application of a single technique or a group of techniques in solving a variety of geological problems which shall be of immense help in planning and execution of the ongoing exploration program in an area are dealt. A number of case studies from different field areas are presented and effective utility of the method in radiometric prospecting are presented and discussed.

After optimization studies on activiated charcoal (ROAC) pellets, the technique has been applied alongwith Thermoluminiscence detection (TLD) and response studied at Lotapahar area of Singhbhum district, Jharkhand. Results of the same are compared with the response obtained from the data collected by CCT and SSNTD techniques in the same area. The survey helped in deciphering structural controls of mineralization and also in deciphering favourable locales to look for mineralization.

Radon emanometry employing the method of CCT has helped in delineating potential areas for sub-surface uranium bearing horizons in Bhandara district of Maharashtra and in discrimination of thoriferous and uraniferous areas. Delineation of radioactive haloes by radiometric survey associated with ‘low’ order magnetic anomaly obtained from non-radiometric geophysical survey helped in precisely demarcating the contact between pegmatites and granitic gneisses besides other structural controls of mineralization in the Suryamalai batholith of Kullampatti area of Tamil Nadu.

Association of radon ‘high’ associated with ‘high’ magnetic signatures and ‘low’ resistivity trends suggestive of fracture zones brought out distinctly in Jamiri area of Arunachal Pradesh helped in tracing the continuity of the fault / fracture zone beneath the soil cover and served as a guide in the ongoing exploration program in the area. A well defined radon ‘high’ deciphering the continuity of the known uranium ore body in the soil covered area in Bodal prospect of Madhya Pradesh helped in planning the exploration strategy in soil covered region of the survey area.

Radon survey carried out in parts of Cuddapah basin over the Ipuru Dome of Guntur district of Andhra Pradesh helped in tracing the extension of the concealed uranium ore body besides locating the fracture / fault zone and in also tracing the extension of the radioactive breccia zone. The information helped in planning the exploration program to be taken up in the survey area.

# MINERAL CHEMISTRY AND GEOTHERMOMETRY OF PANGIDI BASALTS, ANDHRA PRADESH, INDIA

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This paper is aimed at presenting mineral chemistry of clinopyroxenes (CPX), calcic-plagioclase feldspars (PLAG) and Fe-Ti oxides from basalts of Pangidi area ($81^0$32 ?-$81^0$34 $^?$E; $16^0$58 $^?$-$17^0$3 ?N), Andhra Pradesh, southern India. The Pangidi basalts carry phenocrysts of CPX and PLAG and largely altered and insignificant quantities (< 1%) of olivine and glass. Titaniferou-magnetite occurs as microphenocrysts or groundmass, while illmenite occurs only in groundmass. The major element concentrations for CPX and PLAG both in phenocryst and groundmass representing from core and rim portions were determined by Electronprobe Microanalyser. The compositional range of pyroxenes ($Ca_{39}$ $Mg_{46}Fe_{15}$ to $Ca_{31}Mg_{38}Fe_{31}$) revealed that the CPX is composed of dominant augite and subordinate quantity of sub-calcic augite. The chemistry of CPX shows a tendency of moderate enrichment of Fe and depletion of Ca from core to rim suggesting moderate fractionation and cooling of precursors of basalts. PLAG occurs as thin, elongated and tabular laths which shows the variation of An content between 50 and 86% and mostly around 60%. The more An content is noticed at the rim portion than in the core. The potash content hovers around 0.1% and but rarely exceeds 0.2%. Thermobarometry of Fe-Ti oxides from the Pangidi basalts yielded T of crystallization in the range of $1040^0$C and $1100^0$C.

# SESSION - X
# EXPLORATION (CONTINUED)

## ELECTRON PROBE MICRO ANALYZER (EPMA) STUDIES OF BASALT ROCK FROM FLUORIDE RICH GROUNDWATER AREAS OF PANDHARKAWADA TALUKA, YAVATMAL DISTRICT, MAHARASHTRA

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The groundwater from the study area contained as high as ~5 ppm fluoride from shallow aquifers and 17 ppm from deeper aquifers during the pre-monsoon season of 2004. In order to find out the source mineral contributing to high fluorine in the groundwater, two fresh rock samples of basalt were collected from a flow (compound pahoehoe) occurring at 260-280 and 240-260 above mean sea level (amsl). One of the samples is vesicular in nature with amygdales and (ii) the other one is a massive sample. Fluorine content in the bulk samples of vesicular basalt and massive basalt is up to 6.3 ppm and 7.4 ppm respectively. A combined microscopy and Electron Probe Micro Analyzer (EPMA) study was carried out to identify the fluorine bearing phase in the massive basalt sample. The Back Scattered Electron (BSE) image techniques and qualitative analysis indicate that plagioclase feldspar and pyroxene (augite and diopside) are the major modal minerals (95 vol%). No primary fluorine bearing mineral such as fluorite and topaz were found. However, fluorine is contributed by secondary minerals such as apophyllite, zeolites and hydrous mafic minerals like amphiboles and biotite where it is present in the crystal lattices. Therefore the high concentration of fluoride in groundwater from the area is suggested to be not related to fluorine bearing mineral phases. Other factors such as moderate to high alkalinity, high residence time, semi arid climate and sluggish movement of groundwater in compound pahoehoe flows etc are likely to have played a significant role in the fluoride rich nature of the groundwater in this terrain.

*Keywords* : Basalt, Petrography, Groundwater, Secondary minerals and Deeper aquifer.

## HYDROTHERMAL DEPOSITS AT KINGS TRIPLE JUNCTION, NORTHERN LAU BACK-ARC BASIN, SW PACIFIC: PROCESSES OF THEIR FORMATION

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During 19th cruise of R. V. Akademik Mstislav Keldysh in 1990, an inactive hydrothermal field was discovered near Kings Triple Junction (KTJ) in northern Lau back-arc basin. Here we address the processes of development of this hydrothermal field based on the mineralogy and geochemistry of the samples collected by *MIR* submersibles. The field consisted of a large elongated basal 'pedestal' with one main mound at the center and several chimneys on its periphery. The surrounding region is carpeted with lava pillows having ferromanganese 'precipitate' as infillings resembling small "Christmas Tree' scattered within their grooves. Although parts of the same hydrothermal field, all these deposits differ significantly in their mineralogy and elemental composition indicating different temperature of formation. The pedestal slab consisting of chalcopyrite and pyrite as major minerals and rich in Cu is likely to have formed at higher temperatures than sphalerite dominated peripheral chimney. The surrounding oxide growths within lava pillows have two distinct layers, Fe rich orange-red basal part with Mn rich black surface coating, and seem to have formed at very low temperature as precipitates from diffused hydrothermal flows from the seafloor. Based on the similarity in geomorphology of these 'back-arc' deposits with those from 'spreading axis' at 'Mid-Atlantic Ridge' ('TAG' hydrothermal mound) and 'East Pacific Rise' (vent site at 21°N), it can be inferred that, despite differences in tectonic settings, the processes of formation of hydrothermal deposits are similar.

# GEOCHEMISTRY OF THE UNUSUAL CRETACEOUS ULTRAMAFIC DYKE SWARMS ASSOCIATED WITH CONTINENTAL FLOOD BASALTS OF SOUTHERN SAURASHTRA IN WESTERN INDIA

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The igneous intrusive activity in Saurashtra region is characterized by the presence of five different types of dyke swarms which display grain size, mineralogical and textural variations. Out of these five, the unusual ultramafic variety of olivine bearing ankaramite dykes and as well as olivine bearing pyroxenite dykes are studied in the present work. The Ankaramite dykes under study are well exposed in Jasdan-Atkot area, north of Amreli and the olivine bearing pyroxenite dykes are found in Gir forest area to the Southwest of Girnar-Visavadar region. These two ultramafic dyke swarms show dominant E-W trends indicating the pervasive nature of regional fracture/deformation patterns in southern Saurashtra region. Petrologically, the Ankaramite variety of ultramafic dykes are characterized by the presence of large phenocrysts of olivine and clinopyroxene (cpx) which are set in a groundmass of plagioclase, iron oxides and accessory brown amphiboles. The other ultramafic variety of coarse-grained olivine bearing pyroxenite dykes also show porphyritic textures with phenocrysts of olivine, cpx, minor opx and opaques which are set in a mafic rich groundmass. Olivine and clinopyroxenes in these two types of dykes are mostly unaltered in nature and are not recrystallized/metamorphosed. Chemically, the coarse-grained pyroxenites are highly enriched in MgO (16.1 to 17.4 Wt %), Cr (1830 to 1994 ppm) and Ni (570 to 640 ppm) and are depleted in $SiO_2$ (48.17 Wt %) and $Fe_2O_3^T$ (5.52% Wt %) and $TiO_2$ (0.59 Wt %). Chondrite normalized REE patterns of these rocks show slight LREE enrichment ($La/Sm_N$=1.39-1.99), flat heavy REE ($Gd/Yb_N$=1.3-2.0) and absence of Eu anomalies. These REE patterns indicate their derivation from unfractionated mantle sources. The other variety of ankaramite dykes are also characterized by high concentrations of MgO (~10 to 15 Wt %) and exhibit contrasting major, trace element and REE characteristics in comparison to normal tholeiitic variety of gabbro-dolerites in this region. These Ankaramite type dykes show typical fractionated REE patterns with slight LREE enrichment ($La/Sm_N$=1.28-3.03), and sloping/depleted HREE ($Gd/Yb_N$=2.63-3.86). The trace and REE geochemistry of these ankaramite dykes suggest their derivation from high degrees of partial melting of an enriched subcontinental lithosphere leaving behind garnet in the residue and indicate their emplacement at relatively at deeper levels. The occurrence of these high MgO intrusive rocks associated with Continental Flood Basalts of southern Saurashtra in WDVP is very significant as this region is characterized by the presence of widespread positive gravity anomalies and also the existence of deep seated lineaments. The available geological, petrological and geochemical data on these two types of unusual intrusive magmatic rocks, it is suggested that these rocks may form an important and favourable target for PGE.

# MAFIC-ULTRAMAFIC SUITE OF ROCKS OF THE SOUTHEASTERN MARGIN OF CHHATTISGARH BASIN, CENTRAL INDIA —THEIR DISTRIBUTION PATTERN, GEOCHEMISTRY AND ORIGIN

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The Chhattisgarh basin is a major Proterozoic sedimentary basin of Bastar Craton in Central India. The granitic rocks to the south of the Chhattisgarh basin are intruded by mafic–ultramafic suite of rocks of varying mineral composition ranging from kimberlite, pyroxenite, gabbro to dolerite. A number of diamondiferous kimberlites (Mainpur Kimberlite Field, MKF) also form part of them. These intrusives are found within the Bastar Craton close to the Eastern Ghats Mobile Belt (EGMB). The present study is taken up to understand the nature of mafic-ultramafic suite of rocks near the southeastern margin of the Chhattisgarh basin. An integrated aeromagnetic, field and geochemical approach has been attempted to characterize the mafic-ultramafic magmatism.

The mafic-ultramafic intrusives of the study area occur in the form of numerous NW-SE trending dykes within the granitic country lying in the vicinity of the Chhattisgarh basin. Regional aeromagnetic data shows conspicuous E-W magnetic axis displaced by the major NW-SE, and at places NE-SW magnetic breaks. Satellite imageries show NW-SE, N-S and NE-SW trending lineaments. Majority of the mafic-ultramafic intrusives coincide with the NW-SE trending magnetic breaks. In addition, a few NE-SW trending dykes are noted in the area, which cut across the NW-SE dykes. Individual dyke is about 50m wide and extend over few hundred meters along the strike. These intrusives are massive, medium to coarse grained and undeformed.

Petrographic study and geochemical data of these mafic-ultramafic suite of rocks reveal that majority of the dykes are dolerite / gabbroic in composition with few samples plot in pyroxenite field. MgO content of them varies from ~ 4% to 18 wt%. They are olivine-hypersthene to quartz-hypersthene normative and tholeiitic in composition with extreme iron richment in few samples. Both compatible and incompatible elements exhibit higher degree of correlation with MgO, suggestive of comagmatic nature of mafic-ultramafic suite. Most of the samples have evolved Mg numbers (~0.4), indicating fractionation subsequent to the mantle melting. The Mg-rich rock of the suite contains ~0.35% of $TiO_2$ along with high Cr and Ni content, indicative of high degree melting of the source mantle (~30%). These high degree mantle melts were fractionated during the ascent and emplaced along NW-SE fracture system in an extensional tectonic regime.

Some of the fracture systems appear to be reactivated in the post Chhattisgarh period, hosting second generation of mafic-ultramafic suite of rocks, which may be contemporaneous with the kimberlitic intrusives. As the known kimberlite diatremes of Mainpur Kimberlite Field (MKF) are post Khariar in age, some of these lineaments are likely to be genetically related to the intrusion of diatremes in the area. As such, all the diatremes of MKF are located in a linear tract of 12.5 km from Payalikhand to Bahradih near the loci of intersection of more than one lineament. These diatremes appear to have been emplaced in geotectonic conditions favorable for continental alkaline–ultramfic magmatism, along the western shoulders of Khariar Syneclise over the Bastar Archon close to the Bastar Craton-Eastern Ghats Mobile Belt (EGMB) contact.

*Keywords* : Chhattisgarh basin, Bastar Craton, Eastern Ghats Mobile Belt, Mafic-ultramafics, Kimberlite, Geochemistry.

## SIGNIFICANCE OF AEROMAGNETIC AND SPECTROMETRIC SURVEYS IN DELINEATION OF VARIOUS LITHOTECTONIC UNITS - A CASE STUDY FROM RATNAGIRI AND SINDHUDURG DISTRICTS, MAHARASTRA, CENTRAL INDIA

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Regional ground evaluation of airborne geophysical data, magnetic and spectrometric (u, Th, K and total count) of Devgarh–Talere area, Sindhdurg district, Maharastra was carried out with a view to correlate various lithostratigraphic units of the area vis–a–vis different tectonic/structural elements with the aerogeophysical signatures /anomalies. The study area has been covered by geophysical survey and comprises mainly three types of rocks. These are the Deccan basalts, Proterozoic sediments and laterites. Horizontal/sub horizontal basaltic flow of tholeiitic composition is the dominant litho-unit which shows excellent correlation with high aeromagnetic and low spectrometric values. Presence of free iron oxides in the form of magnetite and ilmenite accounts for the high magnetic susceptibility of the Deccan basalts. Relatively magnetically undisturbed areas of moderate to low intensity correlate well with areas of outcrops of

Proterozoic sediments and laterites. The sediments, consisting of a gently dipping sequence of sandstone and shale and occurring as isolated inliers within the Deccan traps / laterite terrain, are comparable with the Proterozoic Badami Group of South India. They correspond with broad low magnetic anomalies and relatively high spectrometric intensities.

The contact between the Badami sediments and the Deccan traps could be accurately demarcated in the airborne geophysical maps, due to their contrasting intensities and patterns, with ground study. Two conspicuous fabrics trending N-S and

E-W (approx), as evident from the contour patterns in airborne geophysical maps, reflect two prominent fracture systems in the area. Two major parallel striking ENE-WSW, one near Kadamwadi and the other near Torsalewadi, could be recognized from the present study.

The southern part of the area, not covered by the airborne geophysical surveys, exposes strongly deformed and metamorphosed gneiss–granitoid–supracrustal assemblages presumably Archaean age, which appears to be the continuation of Karnataka Craton. There are several bands of meta-ultramafic rocks represented by serpentinite, talc-steatite schist and tremolite-talc schist with or without pockets of podiform Chromite within the gneissic country. Minor minerals which are exploited for economic purposes from the area include silica sand, laterite and Deccan basalt.

*Keywords* : Aeromagnetic, Spectrometric, Deccan basalt, Proterozoic sediments, Laterite, Chromite.

## ULTRAMAFIC-MAFIC CUMULATES, CHROMITITES AND VOLCANIC PROVINCES COULD BE POTENTIAL TARGETS FOR PGE EXPLORATION

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Platinum group metals (PGM) have numerous applications either in their pure form or as a variety of alloys combining different PGM or with other metals. The key uses of PGE are mainly as catalysts and alloys; however they have a continually expanding importance in high tech and fuel cell applications. At present India imports almost all the PGM requirements of the country.

In view of this, there is a pressing need for intensive exploration of potential terrains for possible occurrence of platinum group elements (PGE). PGE being siderophile elements occur mostly in the mafic-ultramfic sequences and layered complexes. If we have a detailed look into the PGE occurrence worldwide, it is evident that PGE is being explored and mined mainly in these lithologies. Another area of interest for PGE exploration could be the mafic-ultramfic cumulate sequences of the ophiolite complexes. The basaltic terrains of continental basalt (CFB) volcanism occurring both in the western and the east and north-east parts of India warrant a detailed look for possible occurrence.

In addition, there are many places in the country, where chromitites have been mined in the past and continues to be so in some places, mainly for extraction of chromium. Since chromitites also host PGE in them, it is suggested a detailed look into the PGE content in them is needed. Any success in reducing the dependency on imports of PGM, will be beneficial and provide impetus for such exploration in future. Pilot studies undertaken in the Naga Hills ophiolite belt as well as in the chromitites of the Kondapalli layered complex as also the gabbros of the Ambadongar region in the Deccan Volcanic Province (DVP) have yielded encouraging results. Detailed investigations may shed more light on this aspect.

Further, continental flood basalts such as the Deccan basalts, also warrant a detailed look into their PGE prospects, since the flood basalts of Noril'sk (Siberia) have been found to contain palladium and platinum as by-products along with copper and nickel deposits in them.

# GEOCHEMISTRY OF SALT AFFECTED SOILS IN PURNA VALLEY, MAHARASHTRA, INDIA: THEIR PALEOCLIMATIC IMPLICATIONS

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The geochemical properties of spatially associated black soil (P1-Bramahmanwara P2-Morgaon Sadjwahi, P3-Wadali Sahini) and red soil (P4-Gaywadi, P5-Masod, P6-Pahar purna) developed over basaltic basement in the geomorphic surfaces of alluvial plains in Purna valley were morphometrically examined and physio-chemically characterised to provide information, that are needed to improve agricultural practices. The soils were taxonomically classified upto subgroup level as Vertisols and Alfisols respectively. The study indicates that the geomorphic episodes during early Holocene and early Pleistocene have exerted strong influence on the pedogenic developments in Vertisols which have clayey, dark brown sodic $B_{ss}$ horizons, enriched with $CaCO_3$ nodules and show strong alkalinity (pH of 8.5 -9.0) and in Alfisols, characterized by more than 40 per cent clay, dark brown/red matrix color, natric/ argillic $B_{tn}$ horizons (>) and show very strong alkalinity (pH> 9.5). The strong alkalinity in these soils is due to the proportionate increase in soluble sodium and exchangeable magnesium in association with carbonates. The chemical composition of soils was highly diverse at each location due to high variations in the distribution of silt and clay. Silica is the major component (> 50 %) followed by iron (10.6-18.4%) and aluminium (9.9-17.5%), that show little variations with depth. The Wadhali Sahini soils (P3) have 6.9 to 8.9 per cent of total sodium exceeding calcium (4.1 to 4.6%) and magnesium contents (2.6 to 3.2%) but in Masod (P5) and Pahar purna (P6), sodic soils have more than 2% sodium. All these soils have less than 0.2% manganese content and less than 1.5 % potassium.

Based on elemental affinity, these soils were clustered into two groups. Group-1 has two soils showing more than 50 per cent of variations in clay associated with total and soluble sodium and soluble magnesium, whereas, Group-II has four soils showing maximum variation for soluble sodium and magnesium and exchangeable magnesium. The geochemical heterogeneity existing in these soils, that are expressed through columnar/prismatic structures and elevated concentrations of sodium and magnesium in exchangeable complex. Slickensided horizons in the black soils (Vertisols) are attributed to seasonal rainfall. The hard compact subsoils and distribution of calcium carbonates down the profile in the red soils (Alfisols) have indicated the prevalence of aridity in the past, whereas, presence of argillans (clay pedofeatures) indicate the prevalence of humid climate in the past. The study show that the development of soils in Purna valley is controlled by frequent changes in the climate as drier (semi-arid/arid) and wetter (sub humid/humid) phase during Holocene. All these soils have high base to alumina ratio indicating the development of strong alkalinity and cementation under semi-arid climatic conditions, that has favoured capillary rise and accumulation of soluble salts throughout the profile. Usage of saline groundwater for irrigation has aggravated the sodicity in the surface and sub-surface soils, that has resulted in further structural degradation. Therefore, integrating the knowledge of soils on geochemistry with morphological, physical and chemical properties would help in preventing these salt affected soils from further degradation which is highly significant for the sustainable management of soil environment.

*Keywords* : Geochemistry, Purna valley, Salt affected soils, Structural degradation.

# LATE ABSTRACTS

# WATER-BORNE RADON AND HYDROGEOCHEMICAL BASED URANIUM EXPLORATION IN RAJAMUNDRY SANDSTONE, WEST GODAVARI DISTRICT, ANDHRA PRADESH, INDIA

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The lithology and sedimentary structures of the Rajamundry Formation (Miocene age) indicate that it may be regarded as a typical valley-fill sediment. The formation covers an area of 1100 sq km and is about 600m thick. The formation is composed of sandstone, clay and lignite, and is continental in onshore and marine in the offshore. It is in contact with the Gondwana sediments and Deccan traps.

The Tertiary sandstones are important host for uranium mineralisation. By analogy, in South Texas and Northwest Colorado, USA, the reducing gas (mostly methane, and other hydrocarbon) moving through uraniferous oxidising water has precipitated uranium in the sedimentsespecially along fault planes, on the petroliferous aquifers and hydrocarbon accumulations and, at oil-water interface of hydrocarbon accumulations i.e at the points of introduction of reductant into oxidising ground waters. In this context, Rajamundry sandstone which is a typical valley-fill sediments lying above the natural gas and petroleum bearing Krishna Godavari basin with faults is an important geological setting for uranium mineralisation.

The exploration strategies of hydrogeochemicl survey and water-borne Radon surveys were selected in this soil-covered area. Hydrogeochemical survey carried out in the Rajahmundry sandstone has brought out four (4) hydro-uranium anomalous zones with water samples (10-45ppb) falling around Kadiyadda, Madhavaram, Erramalla and Chinna Malapalle areas of West Godavari district, Andhra Pradesh. These prospective zones are of 9 to 24 sq km area.

Water-borne Radon (Rn) was utilized as a tool for exploration of uranium in this soil covered terrain. Rn contours cluster around two zones around Chinna Tadapalle and in SW of Gollagudem wherein the Rn value is >60counts/50sec/500ml. These Rn anomalies fall within the above mentioned hydrouranium anomalous zones. Gamma ray logging of private bore wells has intercepted relatively high $eU_3O_8$ values of about 20-30ppm in the in Kommugudem, which also falls in the 'high hydrouranium-high radon zone'.

These data and interpretations strongly point to the signatures of uranium mineralization in the Rajahmundry sandstone south of Chinna Tadepalli and SW of Gollagudem. Although this hydrouranium-Rn anomaly is minor but it is significant because it is associated with continental sandstone lying in Krishna Godavari oil and natural gas field which is favorable geological setting for sandstone-type uranium mineralisation.

*Keywords*: Rajamundry sandstone, Hydrouranium anomalies, water-borne Rn anomalies.

# Rb, Sr, AND Ba GEOCHEMISTRY OF COEXISTING GRANITOIDS-PEGMATOIDS FROM THE KAWADGAON-CHALLANPARA AREA, CENTRAL INDIA: IMPLICATIONS FOR RARE METAL EXPLORATION

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The Archaean gneisses and metasedimentary rocks of the Bengpal Group form the oldest lithounits in the Kawadgaon-Challanpara area, central India. These are intruded by the Palaeoproterozoic granitoids and related pegmatoids. The granitoids are exposed over a large tract, and form hill ranges and also low-lying

areas. They are medium- to coarse-grained and have yielded a Rb-Sr isochron age of 2497 Ma, with an initial $^{87}Sr/^{86}Sr$ ratio of 0.7142. Their aureoles display textural and mineralogical gradations from granitoids to pegmatoids. To understand their geochemical evolution, the coexisting granitoids-pegmatoids of the area have been investigated. This paper presents data on the abundances of Rb, Sr, and Ba in the coexisting granitoids-pegmatoids and evaluates their suitability for exploration of rare metals in the area.

Chemically, the granitoids show transition from adamellite to granite. The concentrations of some critical elements in the granitoids are 141-469 (av. 286) ppm Rb, 11-208 (av. 88) ppm Sr, and 50-1188 (av. 558) ppm Ba, whereas, the concentrations of these elements in the pegmatoids are 158-659 (av. 421.1) ppm Rb, 22-91 (av. 47) ppm Sr, and 50-613 (av. 370) ppm Ba. When compared with the abundances of Rb (170 ppm), Sr (100 ppm), and Ba (420 ppm) in the average low Ca-granite, the investigated granitoids show enrichment of Rb (1.7 times), and depletion of Sr (1.4 times less), whereas, the pegmatoids reveal still more pronounced enrichment of Rb (2.5 times), and more depletion of Sr (~2 times less) and less of Ba (1.14 times less). The granitoids have Ba/Rb ratios of 0.24 to 5.02 and Rb/Sr ratios of 0.8 to 38.2, whereas, the pegmatoids have still less Ba/Rb ratios of 0.17 to 1.40 and higher Rb/Sr ratios of 4.74 to 17.81. Some of these values for the granitoids, and all the values for the pegmatoids, indicate anomalously low Ba/Rb and high Rb/Sr ratios for the investigated felsic bodies, as against similar ratios for the average low Ca-granite (Ba/Rb = 2.47 and Rb/Sr = 1.7). Furthermore, a similar trend is also revealed by the Ba/Rb and Rb/Sr ratios of the investigated coexisting granitoids-pegmatoids, when compared with similar ratios for the 'evolved' granite (Ba/Rb = <0.25 and Rb/Sr = >5.0). The data, therefore, reveal that the studied coexisting granitoids-pegmatoids belong to the category of 'evolved' granitoids-pegmatoids, even though certain granite samples fall under the class of normal granitoids. This evolutionary trend of the studied granitoids is further supported by their Rb-Sr-Ba triangular plots in the fields for normal and differentiated granites, whereas, such plots of the pegmatoids fall only in the field for differentiated granite. It, thus, suggests that a major part of the studied granitoids formed from evolved melts, and the coexisting pegmatoids formed from still more evolved melts. Such evolved granitoids-pegmatoids are known for hosting rare metals. Accordingly, the investigated granitoids and associated pegmatoids appear suitable for hosting economic concentrations of rare metals. Interestingly, with respect to 21 ppm of Nb in the average low Ca-granite, the investigated granitoids have more than 2 times the concentrations of Nb (11-147, av. 45, ppm Nb), whereas, the pegmatoids have nearly 7 times enrichment of Nb (36-475, av. 134, ppm Nb). Furthermore, the pegmatoids, genetically related to the investigated granitoids, also carry concentrations of rare metals (Be, Nb, Ta) and some rare earths (La, Ce, Y).

The results of the present study suggests that the coexisting granitoids-pegmatoids of the Kawadgaon-Challanpara area, Bastar craton, Central India, have formed from evolved melts and, accordingly, they are suitable for hosting rare metal concentrations. Therefore, the investigated granitoids and pegmatoids, including their soils/gravels, should be targeted for locating concentrations of rare metals.

## SEDIMENTALOGICAL CHARACTERS OF SRISAILAM AND BANGANAPALLE QUARTZITES AS GUIDING TOOL FOR URANIUM EXPLORATION- A CASE STUDY FROM CHTRIAL AND KOPPUNURU

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The northeastern part of Middle Proterozoic Cuddapah Basin consists of two proven uranium deposits viz. Chitrial located at Srisailam sub-basin and Koppunuru located at Kurnool sub-basin. The basement rock for these sedimentary basins is Mahboobnagar granite, dated 2286 Ma, which has a large contribution both in terms of sediments and their mineralization. Basement granite is unconformably overlain by Srisailam Formation at Chitrial and by Banganapalle Formation at Koppunuru. In terms of gross mineralogy the overlying sediments, mainly quartzites, appear similar but the detailed petrographic studies indicate that the litho units differ both in terms of clast composition and textural aspects which have an important bearing on hosting uranium mineralization. This paper attempts to compare the quartzite of both Srisailam and Banganapalle Formation.

The Srisailam quartzite characterized as subfeldspathic/ feldspathic arenite, is composed of moderately sorted, subangular to subrounded framework clasts bound by matrix and cement. The clasts are predominantly composed of quartz followed by feldspar and a few lithic clasts of vein quartz and granite. Quartz (60-80% of clasts) is represented by both monocrystalline and poly crystalline grains the former being predominant over the later. Feldspar (15-35% of clasts) is represented by orthoclase, microcline perthite and plagioclase. The clasts show wide variation in grain size (200 microns to 2mm), with the average of 1100 microns. The matrix is composed of sericite, chlorite, clay and fine quartz constituting up to 10% of the rock by volume. Secondary overgrown quartz constitute the prime binding cement associated occasionally with ferruginous cement composed of limonite/goethite and makes up to 2% of the rock by volume. Glauconite, tourmaline, rutile and zircon are the accessory minerals. Pyrite, ilmenite and anatase are the ore minerals present. Formation of clay and sericite due to decomposition of feldspars development of secondary quartz as overgrowth in optical continuity with the detrital clasts are the main process of diagenesis. The high proportion of quartz clasts and feldspar reflects the quartz-rich terrain such as granite as its provenance. The presence of fresh feldspar including plagioclase and their moderate sorting indicates that the sediments have not had much transportation and have been deposited near to its source. The presence of glauconite signify marine/ marginal marine environment of deposition.

The Banganapalle quartzite characterized as quartz arenite, consists well sorted, rounded to well rounded framework clasts bound by silica cement. The clasts are predominantly composed of quartz followed by minor feldspar, chert and a few lithic clasts of granite and quartzite. Quartz (up to 97% of clasts) is represented predominantly by monocrystalline grains, with few poly crystalline grains. Feldspar (up to 3% of clasts) is represented by orthoclase, microcline and perthite. The arenite mostly exhibit bimodal distribution with an average grain size of 900 microns and 200 microns representing coarse and fine size population respectively. The epimatrix (~2%) is composed of sericite, clay and fine quartz. Overgrown quartz and calcite constitute the binding cement and makes up to 10% of the rock by volume. Tourmaline zircon and monazite constitute minor accessory minerals present. Pyrite, leucoxene, limonite and anatase are the ore minerals observed. Formation of clay and sericite due to decomposition of feldspars development of secondary quartz as overgrowth in optical continuity with the detrital clasts are the main process of diagenesis. The high proportion of quartz clasts and the presence of chert reflect the recycled quartz rich terrain as its source and the feldspathic constituents signify contribution from granite terrain. The highly rounded nature of the clasts, with well sorted grains and mineralogical maturity indicate that the sediments are of recycled nature. The presence of glauconite, signifies marine/marginal marine environment of deposition.

The uranium mineralization at Chitrial is mainly represented by uraninite occurring as inclusions in feldspar, pitchblende, minor coffinite and secondary urinal minerals occurring along micro fractures. Besides, variable concentration of uranium is associated with biotitic, chlorite, serecitised feldspar, anatase and hydrated iron oxides. Whereas the uranium mineralization at Koppunuru is mainly represented by coffinite, pitchblende and secondary uranyl minerals occurring along micro fractures, grain margins of detrital clasts and as segregations. Besides variable concentration of uranium is associated with biotite, chlorite, sericitised feldspar, anatase, hydrated iron oxides, glauconite and carbonaceous matter.

The feldspathic arenite of Srisailam Formation with irregular streaks of argillaceous material that are composed of clay-sericite and fine streaks of carbonaceous material and pyrite hosts minor and rather sporadic U-mineralization owning to its well indurated and tightly packed nature with little or no pore spaces available for the flow of mineralizing fluid and imply that it’s a depositional aquitard. It largely acted as cover rock for U-mineralization occurring below and along the unconformity plane. Whereas, the quartz arenite of Banganapalle Formation with presence of abundant colloform pyrite and carbonaceous matter hosts scaly clusters, stringers and veins of coffinite, colloform aggregates of pitchblende and secondary uranyl minerals along grain margins of detrital clasts indicating that it is a depositional aquifer with lot of pore spaces available for movement of mineralizing fluids and their precipitation with the presence of suitable reductants.

Thus with reference to depositional history, the mineralization appears to be post diagenetic in case of Srisailam quartzite which can not hold much uranium resulting in concentration of U-mineralization mainly by granite (>90%) at Chitrial area whereas for Banganapalle quartzite its pre to syn diagenetic with lot of available pore space for mineralizing fluids to get precipitated mainly in sedimentary units above unconformity at Koppunuru which is well corroborated by exploratory drilling in these areas.

## ENVIRONMENTAL MONITORING OF GROUNDWATER CHEMISTRY AND POTABILITY AROUND KOPPUNURU URANIUM DEPOSIT, GUNTUR DISTRICT, ANDHRA PRADESH

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Monitoring of ground water chemistry in Koppunuru area is being carried out as a part of periodic environmental baseline data generation with an objective to understand the pre-mining, prevailing environmental scenario around the established mineralised area. Groundwater sampling (n=16) is being carried out over an area of 12.50 sq km, over 2 km radial distance around Koppunuru village encompassing the entire mineralised area. Controls of groundwater chemistry, its variation in pre-monsoon, monsoon and post-monsoon seasons and potability in terms of drinking water and irrigation usages are presented in this paper.

Ground water around Koppunuru area is mildly alkaline in nature with various parameters viz pH (6.8-8.5, X = 7.9), TDS (280-4050ppm, $\overline{X} = 1173$), $F^-$ (1.00-1.80ppm, $\overline{X} = 1.28$), $SO_4^{2-}$ (10-1200ppm, $\overline{X} = 155$), Ca (22-315ppm, $\overline{X} = 91$), Al (248-4341ppm, $\overline{X} = 1395$), Zn (6-3430ppb, $\overline{X} = 304$), Mg (8-100ppm, $\overline{X} = 47.8$), Cu (10-50ppb, $\overline{X} = 18$), Ni (10-27ppb, $\overline{X} = 15$), Mn (7-308ppb, $\overline{X} = 108$). Anion content wise groundwater is carbonate/ bi-carbonate depleted and chlorine rich in pre and post monsoon season but there is increase in $SO_4^{2-}$ content in the monsoon season. Total dissolved salt (TDS) content is high in this area (<1000 ppm average) and show strong positive correlations with $Cl^-$, $Ca^{2+}$, $Mg^{2+}$, $Na^+$, $SO_4^{2-}$ and conductivity in both pre and post monsoon seasons. Cation content wise groundwater is $Ca^{2+}$ depleted and $Na^+$ rich in pre monsoon season with marginal increase in $Mg^{2+}$ content during monsoon and post- monsoon seasons.

Uranium does not show any significant correlation with other cation, anion or radicals in pre-monsoon season, but it shows strong positive correlation with $SO_4^{2-}$ (r=0.967), total salt concentration(r=0.851), $Na^+$ (r=0.847), $Cl^-$ (r=0.712), and TDS (r=0.717) in post- monsoon season. The sediment and granite hosted subsurface uranium mineralisation in Koppunuru area has contributed to the anomalous hydro uranium values (3 to 902 ppb) in groundwater. Correlation of uranium and TDS is also explained by the similar fluctuation and trend in periodic values for conductivity total dissolved solids (TDS) and uranium.

The major ion chemistry coupled with Gibbs ratio plot indicates that the chemistry of groundwater is controlled mainly by the chemical interaction between aquifer rocks and groundwater and to some extent by processes like evapo-transpiration etc. The extent of interaction however depends upon factors like residence time of water within the aquifer, topographic condition, continuous irrigation practices, and anthropogenic (fertilizers) activities. The annual rainfall and ground water recharge of the area is not significant; the process of evaporation might have incorporated some component of sodium and chlorine ion.

Chloro-alkaline indices, (CAI = Cl- (Na+K) / Cl) were calculated (after Schoeller, 1977) to study the process of ion exchange between the ground water and its host environment during rock – water interaction.

During pre- monsoon season, mostly positive CAI values were noted for the studied groundwater samples which suggest that sodium and potassium from water are exchanged with magnesium and calcium in rock following Base Exchange reactions (chloroalkaline equilibrium). In contrast, during monsoon and post-monsoon seasons, mostly negative CAI values were obtained for the same samples suggesting that magnesium and calcium from water are exchanged with sodium and potassium in rock favouring cation-anion exchange reactions (chloroalkaline disequilibrium).

On comparison with the drinking water standards, although concentrations of hazardous parameters like F, As, Fe, Pb, etc are within the desired limits of drinking water quality (WHO, 1984 and BIS, 1991), the groundwater of the area is affected by excess salinity with higher TDS content greater than the prescribed limits (maximum in pre monsoon).

Based on the values of SAR and % $Na^+$ in relation to total salt concentration, groundwater is categorized as of poor quality for irrigation purpose. In pre-monsoon season, five samples (30%) show higher %$Na^+$ (>60) whereas during monsoon and post monsoon period, four samples (40%) and two samples (15%) show higher %$Na^+$ (>60) respectively. Although based on %$Na^+$ values groundwater can be considered marginally suited for irrigation purpose, but based on the high total salt concentration the GW falls in the 'unsuitable' class.

*Keywords*: Chloroalkaline indices (CAI) , Uranium, Evapo-transpiration, Potability, Total dissolved salts (TDS), Sodium absorption ratio (SAR), Bureau of India Standards (BIS).

## PETROMINERALOGICAL ASPECTS OF URANIUM MINERALISATION IN KALADGI-BADAMI BASIN AT DESHNUR, BELGAUM DISTRICT, KARNATAKA

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The Meso-Proterozoic Kaladgi-Badami Basin is located in the north western parts of Karnataka and in parts of Maharashtra. Exposed over an area of 8300 sq km, with a sediment thickness of 4527m, the Kaladgi-Badami formations have been divided into two groups displaying distinct characteristics in terms of stratigraphic succession, lithologic assemblage, tectonic and structural features. Statigraphically it consists of Archaean Basement rocks comprising granites, gneisses and schists overlain by argillaceous and carbonate sediments of the Lower Bagalkot Group. The Badami Group which unconfirmably overlies the Bagalkot Group sediments comprise predominantly of arenaceous sediments. The Bagalkot Group is deformed displaying tight isoclinal folds while the Badami Group sediments display only minor warping. The E-W, NE-SW and NNW-SSE trending major faults affect both basement and sediments.

Integrated exploration efforts by Atomic Minerals Directorate in the Kaladgi-Badami Basin, over three decades, resulted in locating significant uranium mineralisation at Deshnur ($15^0$ 55"N: $74^0$ 44"E) during the field season of 2004-2005. This mineralisation is associated with the Badami arenites of the Kerur formation. The radioactive samples are mostly pebbly quartz arenite, quartz arenite, brecciated quartz arenite all belonging to the Badami group. Framework clasts comprise dominant monocrystalline quartz with a few clasts of polycrystalline quartz, chert and metaquartzite. The matrix comprises clay identified, as kaolinite (XRD lab); as a minor to accessory component. Majority of the sedimentary units are modified by diagenetic effects of silica, with chert overgrowth on quartz grains. Though chert and silica cement constitute more than 90% of the cement, pyrite cement is more pronounced in sediments of Deshnur area. Alteration features such as kaolinisation of feldspars is also more pronounced in this area. The basement rocks of

Deshnur display a high degree of deformation as indicated by intense shearing and brecciation. Deformational features like pulverisation, fracturing, elongation, undulose extinction, Boehm twin lamellae are observed in quartz grains.

In Deshnur area, seven radioactive phases have been identified. They are pitted uraninite, pitchblende, coffinite, secondary uranium minerals along fracture planes and intergranular spaces, labile uranium present along grain boundaries, adsorbed uranium in kaolinite, and substitution in refractory minerals like zircon. Quartz is the major clast component in these rocks. Detrital composition of the clasts comprises almost entirely quartz. Textural features like, rounded to oval grains with varying sizes from 0.2mm to >2mm, indicates moderate textural maturity. The different types of quartz identified are a) monocrystalline quartz with symmetrical extinction implying *igneous source*, b) polycrystalline quartz with sub-equal grains, again *igneous origin*, c) polycrystalline quartz (metaquartzite) with elongated grains and crenulated margins suggesting *metamorphic origin*, and d) monocrystalline quartz (chert) with overgrowth implying *sedimentary source*. Predominance of monocrystalline quartz indicates igneous source. Sulphides are the major ore minerals in the U- mineralized samples and they are identified as pyrite, with accessory amounts of marcasite, chalcopyrite, chalcocite, and covellite. The other ore minerals identified are native silver and oxides like haematite and limonite. The uranium mineralisation at Deshnur appears to be hydrothermal epigenitic type as indicated by the presence of pyrite and pitchblende along fractures and pitchblende along fractures in pyrite and the intergranular spaces. From the mineral assemblage and textural associations it is inferred that the temperature of mineralisation is epi- to mesothermal in the range of 100-300$^0$C and is *fracture-controlled*. From the mineral assemblage and textural relationships an attempt has been made to understand the paragenetic sequence. The following sequence is inferred; rounded uraninite (syngenitic) pre-ore phase > pitchblende/ coffinite (coffinite precipitated during phases of high silica activity); U in substitution in zircon > labile uranium > brannerite > secondary U minerals.

*Keywords*: U-mineralization, Vein type, Proterozoic, Kaladgi-Badami basin. Deshnur, Belgaum district, Karnataka.

## COMPOSITIONAL CHARACTERIZATION OF ZIRCONS IN GRANITOIDS, NW MARGIN OF CUDDAPAH BASIN, DAMARCHERLA AND CHITRIYAL, ANDHRA PRADESH, INDIA-WITH AN EMPHASIS ON THE DISTRIBUTION OF Hf, REE, U AND Th AND THEIR IMPLICATION

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The eastern part of the Dharwar craton (EDC) is dominated by anatectic variant of granite of Late Archean to Paleo-Proterozoic, through rejuvenation of older crust [TTG]. Besides these, there are a number of smaller granite stocks that intrude the Peninsular gneisses and the supracrustal sequences. A number of such granitoids were identified during the survey and exploration by AMD as potential hosts for U and other RMRE.

The zircons occur as one of the important accessory HFSE-bearing minerals in the granitoids of varying composition. The simple structure of $ZrSiO_4$ becomes complex when they incorporate other elements viz. U and Th, REE, Y and Hf. Although there is a complete solid solution between zircon and hafnon ($HfSiO_4$), the Hf content of most natural zircon crystals is 1 to 3 wt percent $HfO_2$. However, their variation is mainly contributed due to the differentiation and evaluation of the host granitoid.

The subtle variations in the chemistry of host granitoid are directly or indirectly imprinted on the co-crystallized zircons formed from the same magmatic fluid, which is highlighted by the varying distribution of Hf, REE, U and Th. Thus, the genetic aspects on granitoid formation can be inferred. An attempt has been made to evaluate the zircons of granitoids from the NW margin of Cuddapah basin, especially from Palnad sub-basin of Andhra Pradesh.

The paper documents and discusses the Electron Probe Micro-analysis [EPMA] based mineral chemistry of two different variants of zircon: Type-1 and Type-2 from fertile and mineralized (uranium-bearing) vis-a-vis the geochemical characteristics of selected granitic bodies that were responsible for uranium mineralization in this part of the Peninsular India. The study revealed that these two types of magmatic zircons have distinct chemistry. The Type-1 zircons are invariably euhedral, round as well as elongate crystals, zoned, usually associated with the early major minerals. These are more abundant in granite and monzo-granite plutons and they have higher amount of $UO_2$ (2.06-4.9%), $HREE_2O_3$ (2.2-3.7%) and $Y_2O_3$ (1.54-2.88%). The Zr/Hf ratio in such granitoids vary from 21-28. The replacement of Zr by tetravalent cations, viz. Hf , Th and/or U is favored in the most evolved granites. Type-2 zircons, on the contrary, are characterized by smaller and more equant crystals, unzoned, and usually interstitial to the rock-forming minerals, and form clusters with other accessory minerals. The second type is more abundant in granites to granodiorite. They also show comparatively lower concentration of Hf (1.13-1.48% $HfO_2$), U (0.16-1.47% $UO_2$), Th (0.01-0.92% $ThO_2$), Y (0.66-2.22% $Y_2O_3$), and $REE_2O_3$ (0.15-2.54%) and at times less analytical total (~ 91.2%). The Zr/Hf ratio in these granitoids is higher (30-43), which indicate lesser differentiation and less evolved nature. Certain analyzed micro-domains of selected zircon grains with low analytical totals (91–98 wt %) indicate distinct substitution at tetravalent structural site than the tetrahedral site. The intense micro-fracturing of zircons could be responsible for the mobilization of U than REE and Hf. These elements could be mobilized only by later intense hydrothermal activity with higher fugacity of oxygen and fluorine at relatively higher temperature. Though, the presence of U and Th induce radiation damage in the structure of zircon, the liberation of intrinsic U and Th from such phenomena are not that dominant. However, such structural disturbances, combined with metamictization, could have made the zircons susceptible for alteration.

## TRACE ELEMENTS DISTRIBUTION IN RADIOACTIVE BANGANAPALLY QUARTZITE FROM KOPPUNURU AREA, GUNTUR DISTRICT, ANDHARA PRADESH, INDIA

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The wavelength-dispersive X-Ray fluoresce spectrometry [WDXRFS] has been widely used as an accurate and precise non-destructive analytical technique for the determination of major and minor elements [1ppm to 100 %] in geological [rock and soil] samples. The sedimentary rocks, especially quartzites of Proterozoic age overlying the unconformity at the contact with basement granitoids, in parts of Srisailam-Palnadu basins, Koppunuru, Guntur district, A.P., are the hosts for a number of uranium occurrences as well as a deposit. The uranium minerals reported in the Banganapally quartzite are pitchblende, coffinite and mixed phases of U with Ti, Si, Al, Ca, P and Pb besides sulphides like pyrite, chalcopyrite and bornite. Though the area has been under exploration and in-depth geochemical evaluation, based on the calibrations made with international standards, an attempt has been made in this paper to present the trace elemental distribution of fifteen elements viz., Cr, Ni, Cu, Zn, Ga, Rb, Sr, Y, Zr, Nb, Ba, Ce, Pb, Th and U, determined on thirty [30] radioactive Banganapally quarzites from the area.

The WDXRFS data revealed significant trace elements distribution in the radioactive quartzite and the samples analyzed Cr (37-208; avg.66 ppm), Ni (<10-43; avg.18 ppm), Cu (15-34; avg.18 ppm), Zn (<10-380; avg.121 ppm), Ga (<10-116; avg17 ppm), Rb (10-223; avg.48 ppm), Sr (<10-35; avg.16 ppm), Y (35-109;

avg.39 ppm), Zr (22-100; avg.89 ppm), Ce (17-62; avg.24 ppm), Pb (118-768; avg.275 ppm), Th (10-54; avg.16 ppm) and U (10-5786; avg.1647 ppm). The uranium values, though of semi-quantitative nature in some of the samples, their abundance in relation to co-existing samples is suggestive of it's nature of dispersion in the system. However, the coefficient of variation is minimum in niobium (41) and maximum in uranium (136). Such variation in the concentration of elements, especially Y, Zr, Th and U and presence of different U-phases already identified in the area indicate wide dispersion of radioactive elements within quartzite.

## MINERAL CHEMISTRY AND CHEMICAL AGE OF URANIUM MINERALS IN METASEDIMENTARY ROCKS OF TURAMDIH, STB, JHARKHAND, INDIA

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The Singhbhum Thrust Belt (STB) in parts of Jharkhand and Orissa is the major uranium producing province in India. The 200 km long and arcuate thrust belt hosts a number of uranium deposits, viz. Kanyaluka, Bagjata, Jaduguda, Narwapahar, Bhatin, Turamdih and Mohuldih. The Turamdih U-deposit located in between Tatanagar and Badampahar form the western part of STB, comprise of three main uranium lodes [0.03 to 0.04 % $U_3O_8$] namely Turamdih-west, -south and -east. These deposits are hosted by the schistose members of the Dhalbhum Formation. However, the lithological units with uranium mineralization are chlorite-quartz schist (with magnetite and apatite), chlorite-sericite quartz schist and feldspathic schists.

The Turamdih mine samples investigated are mainly of chlorite quartz schist and quartz chlorite schist with magnetite and apatite. Contrary to the general presence of sulphides along the STB, these samples have rare sulphide. Few samples show fracturing and brecciation. The radioactivity in these sections is mainly due to uraninite, and minor monazite and xenotime. The uraninite**,** the principal uranium mineral occurs mainly as dissemination in the form of fine anhedral grains (upto 100 microns) as well as fine specks, that are spread all over the sections, besides clustering at places.

On an average most of the uraninites show $UO_2$: around 75 wt %, low $ThO_2$ (0.07-1.50 Wt. %), PbO: around 15 wt % and RE2O3: around 3 wt%. However, some uraninites show high $ThO_2$ (4.09-7.88) and comparatively low $UO_2$ (66-73 %), indicating replacement of uranium by thorium at higher temperature. In all the uraninites, yttrium content is reasonably high ($Y_2O_3$: 2.24 to 3.43 wt %). Chemical ages calculated for these uraninites range mainly from 1100 Ma to 1500 Ma, wherein high thorium uraninites always tend towards higher chemical age.

The fine to medium grained and semi rounded monazite with little alteration shows negligible thorium. Absence of thorium is compensated by the higher concentration of total rare earths in monazite. The fine grained and rounded xenotime shows rare earth oxides up to 24.24 wt %, with almost negligible thorium. Thus, multiple generations of uraninites of varying chemical ages are envisaged, which point towards the possible multi-episodal emplacement of uranium in the area.

# LEGAL AND REGULATORY MEASURES FOR CLEAN DEVELOPMENT MECHANISMS AND CARBON SEQUESTRATION

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Carbon dioxide ($CO_2$) is consumed and stored by plants through photosynthesis. As the plants die out, the carbon-bearing leaves, stems and roots decay to form soil-organic matter. This basic process is called *carbon sequestration*. Essentially, carbon sequestration is a process of transfer of carbon from atmosphere to soil.

## GLOBAL WARMING

The consequences of global warming are somewhat speculative, but potentially severe. Among the possible impacts of global warming are rises in ocean and sea levels, altered marine ecosystems, destruction of coral reefs, spread of disease vectors, especially for insect born infectious diseases, more intense and severe weather patterns, regional potential variation in agricultural production, altered patterns of precipitation and other changes in the hydrologic cycle, increased desertification, increased forest loss, and substantial loss of biodiversity.

Atmospheric carbon dioxide and other greenhouse gases act to trap heat that is reflected from the earth's surface. This buildup of heat could lead to global warming. Through carbon sequestration, atmospheric carbon dioxide levels are reduced as soil organic carbon levels increase. If the soil organic carbon is undisturbed, it can remain in the soil for many years as stable organic matter. This carbon is then sequestered or removed from the pool available to be recycled to the atmosphere. This process reduces $CO_2$ levels in the atmosphere, reducing the chances of global warming.

## CARBON EMISSIONS:

Carbon is an essential element for all life on earth. It is found in the atmosphere in various forms; it is dissolved in the oceans; and it is a major component of many soils and rocks. Carbon is cycled continuously through the biosphere, the atmosphere, the soils and the oceans as a result of natural forces. Understanding the carbon cycle is essential to understand the causes and cures of climate change. It has been estimated that 20 percent or more of targeted $CO_2$ emission reductions could be met by agriculture soil carbon sequestration.

In parts of the world that have signed the Kyoto Agreement, carbon markets have already began. In the United States a volunteer market exists called the Chicago Climate Exchange. It is possible that a private system of trading will be established, which could pay producers per hectare of management change or per ton of carbon sequestered. It is also possible that the government will provide certain incentives for producers to sequester carbon. In any case, carbon sequestration would increase soil organic matter due to:

a) improved soil structure and quality

b) improved soil productivity through increased organic matter

c) reduced erosion through improved soil structure, and

d) improved water quality through reduced erosion

Economic potential is estimated by factoring the trade-off between the additional costs of sequestering practices, relative to the additional returns from the carbon payments into farmers' adoption decisions. Models have predicted that farmers would adopt cropland management (primarily conservation tillage) at the lowest carbon price, $10 per metric ton.

A team of US scientists at 10 universities and government laboratories form the Consortium for Agricultural Soils Mitigation of Greenhouse Gases. With federal funding, this group will provide the science and technology necessary to help our nation realize the benefit of carbon sequestration. CASMGG brings together the nation's top researchers in the areas of soil carbon, greenhouse gas emission, conservation practices, computer modeling and economic analysis. CASMGG is also working with international scientists on carbon mitigation efforts.

## POLICIES DESIGNED TO REDUCE EMISSIONS

Nations have a variety of strategies that they might pursue in attempting to discourage the emission of greenhouse gases. Because fossil fuel consumption is the greatest source of greenhouse gas emissions, emissions control strategies will likely be directed toward the energy sector. Several options are available. A nation might enact a carbon tax that would be assessed on the basis of carbon emissions. To avoid or minimize the tax owed, emitters would have an incentive to switch fuel sources, to improve efficiency, and to adopt conservation measures. Historically, the United States has been reluctant to implement pollution taxes.

As an alternative, a nation might adopt technology forcing emissions standards that would apply to classes and categories of emitters. This is the strategy used in the United States to control conventional pollutants under the Clean Water Act. A variation on the theme requires that products manufactured for resale attain certain specified efficiency standards.

Examples include efficiency standards for appliances, water use standards for toilets, and CAFE standards for automobiles. Closely related to efficiency standards are command and control regulations that mandate the use of certain technologies to minimize emissions. Examples could include a requirement that landfills or large confinement feedlots capture and reuse methane generated from normal operations. The difficulty with command and control regulations is that they tend to be inflexible and are often inefficient. At least some command and control regulation, however, is likely to be a feature of domestic greenhouse gas legislation.

A third alternative approach is a cap and trade system where the emissions of individual emitters are capped at some level that forces an aggregate decrease in emissions, but where parties are allowed to trade allowances among themselves. The United States has had great success with such a program with respect to sulfur dioxide under the Clean Air Act. To the extent that caps are placed on greenhouse gas emissions by particular emitters, emissions allowances might be created that can be freely traded permitting reductions to occur at the least cost. A cap and trade system at the national level would mirror the system being put in place under the Kyoto Protocol at the international level. Given its strong advocacy of market based solutions during international negotiations, it is likely that a cap and trade system would be a component of any sophisticated climate change regulatory program adopted in the United States.

The broad scientific view is that the increase in global average temperature above pre-industrial levels ought not to exceed 20 C. Achieving of this goal could be possible by reducing at least 50% of global emissions by 2050. This goal of 50% reduction in current global emissions by 2050 will also not suffice to limit global warming to 20 C. It is assessed that only a global 85% reduction (from 2000 levels) will have a high chance of preventing a 20 increase. The current world per capita emission (PCE) is 4.48 t of $CO_2$ equivalent per year. An 85% reduction means that PCE should drop to 0.67 t of CO2 per year by 2050. As on date, India's PCE is around 1.2 t per year while the average of developed countries is 10 t. This will have an adverse impact on the emerging economies like India and China whose emissions have grown in recent years because of their economic growth but may be forced to accept these legal binding cuts during the period under reference.

Another set of alternatives involves public efforts to make fundamental changes in the sources of energy used in a country. A nation might choose to invest in or subsidize the development of energy sources that don't result in significant emissions of greenhouse gases. Hydropower, nuclear power, and power from various renewable energy sources such as solar power and wind power would be favored. A nation might also increase research efforts designed to develop alternative sources of energy such as hydrogen fuel cells or fusion power.

Finally, a nation might choose to discourage emissions by regulating or taxing activities that directly or indirectly cause such emissions. For example, a nation might subsidize mass transit and tax private automobiles. It is likely that most nations would pursue a variety of approaches in attempting to minimize the emission of greenhouse gases, although it is too early to anticipate specific programs. Given the potential significant economic impact of controls, particularly carbon controls, it is likely that nations will search for innovative, cost effective measures.

## POLICIES DESIGNED TO PROTECT AND ENHANCE SINKS

A nation might also attempt to meet its commitments by undertaking activities that enhance the ability of sinks to remove greenhouse gases from the atmosphere. Most of these efforts involve land use choices or restrictions.

To date, most of the attention regarding enhancement of sinks has been directed toward forestry practices. That is not surprising because forests have a great potential to sequester carbon. Nations that are engaged in deforestation by, for instance, converting forestland to agricultural land, are contributing to the buildup of greenhouse gasses through their land use policies. Moreover, the Kyoto protocol specifically refers to deforestation, reforestation, and afforestation, although the terms are not defined.

## CARBON SEQUESTRATION LEADERSHIP FORUM (CSLF)

The Carbon Sequestration Leadership Forum (CSLF) is a Ministerial-level international climate change initiative that is focused on the development of improved cost-effective technologies for the separation and capture of carbon dioxide ($CO_2$) for its transport and long-term safe storage. The mission of the CSLF is to facilitate the development and deployment of such technologies via collaborative efforts that address key technical, economic, and environmental obstacles. The CSLF will also promote awareness and champion legal, regulatory, financial, and institutional environments conducive to such technologies.

### CSLF Partners

The CSLF is currently comprised of 24 members, including 23 countries and the European Commission. CSLF member countries represent over 3.5 billion people, or approximately 60% of the world's population. Membership is open to national governmental entities that are significant producers or users of fossil fuels and that have a commitment to invest resources in research, development and demonstration activities in $CO_2$ capture and storage technologies.Members of the carbon sequestration stakeholder community are involved with the CSLF and are encouraged to participate and interact with the CSLF.

## CSLF GOALS

The CSLF Charter, established in 2003, establishes a broad outline for cooperation with the purpose of facilitating development of cost-effective techniques for capture and safe long-term storage of $CO_2$, while making these technologies available internationally.

The CSLF will seek to:

- Identify key obstacles in achieving improved technological capacity;
- Identify potential areas of multilateral collaborations on carbon separation, capture, transport and storage technologies;
- Foster collaborative research, development, and demonstration (RD&D) projects reflecting Members' priorities;

- Identify potential issues relating to the treatment of intellectual property;
- Establish guidelines for the collaborations and reporting of their results;
- Assess regularly the progress of collaborative R&D projects and make recommendations on the direction of such projects;
- Establish and regularly assess an inventory of the potential areas of needed research;
- Organize collaboration with all sectors of the international research community, including industry, academia, government and non-government organizations; the CSLF is also intended to complement ongoing international cooperation in this area;
- Develop strategies to address issues of public perception; and

Conduct such other activities to advance achievement of the CSLF's purpose as the Members may determine.

## INTERNATIONAL RECOGNITION

In 2005, the CSLF and the technologies it seeks to develop were identified by international bodies as pivotal in dealing with greenhouse gases and their ultimate stabilization. In July 2005, the G-8 Summit endorsed the CSLF in its Gleneagles Plan of Action on Climate Change, Clean Energy and Sustainable Development, and identified it as a medium of cooperation and collaboration with key developing countries in dealing with greenhouse gases. In 2006 and 2007, the International Energy Agency (IEA) and the CSLF held a series of three workshops for invited experts from around the world on the topic of near-term opportunities for carbon capture and storage (CCS). Resulting recommendations from these workshops were formally adopted by the CSLF and were sent forward to G8 leaders.

## LEGAL AND REGULATORY FRAMEWORK

The regulatory challenge is complex because climate change is a global problem. The problem also is complex because anthropogenic greenhouse gases are emitted as a consequence of activities that generally are conceded to be essential to economic development. Furthermore, the problem is complex because greenhouse gas emissions are widely scattered across the planet.

The fact that climate change is a global issue means that no nation can capture the benefits of regulation for its own citizens absent cooperation of the international community. The fact that greenhouse gas emissions are associated with economic activity means that the cost of greenhouse gas abatement likely will be significant. It also brings into sharp focus the differences between the developed world and the developing world. The world's developed economies are highly dependent on energy consumption, much of it derived from fossil fuels. Developing countries are poised to greatly increase their consumption of energy, and hence their contribution of greenhouse gases to the atmosphere, as they strive for economic equality with the developed world.

Finally, the fact that greenhouse gas emissions are widely dispersed across the planet means that one cannot achieve success solely by forging an agreement between the 10 or 12 largest emitters, particularly when so many developing countries have the potential to greatly increase their contribution to the buildup of greenhouse gases in the atmosphere. The international agreements that have been negotiated to date, and the national programs that have been proposed, are all of recent vintage and all reflect the difficulties discussed above. The legal environment is necessarily evolving as nations struggle with the complexities of global warming. Not surprisingly, many of the emerging legal rules are frustratingly vague and incomplete.

# LEGAL AND REGULATORY MEASURES FOR CLEAN DEVELOPMENT MECHANISMS AND CARBON SEQUESTRATION

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## BACKGROUND

The Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC) was adopted by more than 150 countries at the third session of the Conference of the Parties to the UNFCCC in Kyoto, Japan, on 11 December 1997. It is an international treaty containing binding constraints on greenhouse gas emissions and, mechanisms aimed at cutting the cost of reducing emissions and establish global markets for Green House Gas (GHG) emission permits. Under the Kyoto Protocol, industrialized countries and countries with economies in transition will reduce their combined GHG emissions by at least five per cent below their 1990 levels by the first commitment 2008 to 2012. The most important GHG is carbon dioxide ($CO_2$) whose emissions are mainly related to combustion of fossil fuels.

The Protocol shall enter into force on the ninetieth day after the date on which not less than 55 Parties to the Convention, incorporating Annex I Parties which accounted in total for at least 55 % of the total carbon dioxide emissions for 1990 from that group, have deposited their instruments of ratification, acceptance, approval or accession.

The Kyoto Mechanisms encompass the following three instruments:

- Joint Implementation (JI, Article 6 Kyoto Protocol) projects in other Annex B countries that lead to Emission Reduction Units (ERUs),
- Projects in countries without emission targets (Clean Development Mechanism (CDM), Article 12 Kyoto Protocol) that lead to Certified Emission Reductions (CERs), and
- International Emission Trading (IET, Article 17 Kyoto Protocol) of Assigned Amount Units (AAUs) among Annex B countries.

The concepts of JI and CDM refer to project based co-operations between two countries, where GHG emission reductions take place in the country with lower marginal abatement costs. In other words, a country that has adopted a quantified GHG emission reduction or limitation commitment under the Kyoto Protocol can fulfil parts of this commitment on the territory of another country where the costs are lower. The CDM envisages a project co-operation between industrialised countries with commitments (Annex I countries) and developing countries (non-Annex I countries), which have exempted from quantified commitments under the Protocol (JI refers to a project-based co-operation between two industrialised countries).

The main benefits that can be expected from the project-based Kyoto mechanisms are, on the one hand, that they potentially reduce industrialised countries' costs of meeting the Kyoto Protocol targets, whereas, on the other hand, they are to support the host countries objectives regarding sustainable development.

With the help of CDM, countries which have set themselves an emission reduction target under the Kyoto Protocol (Annex I countries) can contribute to the financing of projects in developing countries (non-Annex I countries) which do not have a reduction target. Contributing to the sustainable development of the host country, the project should reduce the emission of greenhouse gases. The achieved emission reductions can be used by the Annex I country in order to meet its reduction target.

**The Kyoto Protocol (Article 12.10) envisages that CDM projects could start from 2000 onwards, but the required regulatory and institutional framework is not yet in place**.

## APPLICABILITY OF CLEAN DEVELOPMENT MECHANISM IN COAL MINING SECTOR

Clean Development Mechanism can be adopted through following methods in coal mining

· Coal Bed Methane Capturing

· Filling of underground voids with $CO_2$ and other GHGs

· Carbon sequestration through development of large scale afforestation in mined out areas.

## COAL BED METHANE CAPTURING:

Methane is a powerful green house gas, as its adverse impacts are felt more intensely due to its shorter residence and higher potency in the atmosphere than carbon dioxide.

Methane is associated with coal as a by product of the coal formation process. It is trapped in coal beds and released during and after mining. This methane does cause disasters in underground coal mines.

If effectively recovered, coal bed methane associated with coal reserves and emitted during coal mining could be a significant potential source of energy.

Methane capture and its utilization from coal mines is not being undertaken in India due to:

· Lack of latest technology

· Lack of expertise and experience

· Pervasive perception that commercial viability of exploitation and utilization of Methane is doubtful.

The CBM resources of India as per Directorate General of Hydrocarbons (DGH), Ministry of Petroleum & Natural Gas (MoP&NG) is :

**Additional resource is available in block located in south west Raniganj (approximately 200 Sq.Km) allotted to M/S GEECL by FIPB for which data is not available. Coalmine methane resource is not yet accounted.**

Brief description of the specific options for utilisation of CBM:

a.Power Generation

CBM can be ideal fuel for co-generation Power plants to bring in higher efficiency and is preferred fuel for new thermal power plant on count of lower capital investment and higher operational efficiency.

b.Auto Fuel in form of Compressed Natural Gas (CNG)

CNG is already an established clean and environment friendly fuel. Depending upon the avaibility of CBM, this could be a good end use. Utilization of recovered CBM as fuel in form of CNG for mine dump truck is already part of demonstration project titled “Coalbed Methane Recovery & Commercial Utilization Project” presently under implementation in collaboration with UNDP/GEF at Sudamdih and Moonidih mines of BCCL.

c.Feed stock for Fertilizer

M/S Sindri Modernization Plant (SMP), Sindri is utilizing fuel oil as feedstock for its cracker complex. The installed capacity of this plant is 900 tonne per day ammonia and is operational at 80% of capacity during last three years. The CBM produced from Jharia, Bokaro coalfields can be utilized at Sindri, which will economise the operations.

d.Fuel for Industrial Use

It may provide an economical fuel for a number of industries like cement plant, refractories, Rolling mills etc. in Dhanbad, Bokaro, Palamu regions in view of the superior combustion properties of CBM. According to survey carried out by MECON (I) Ltd, there is demand of 5000000 Nm3 of natural gas/CBM in the Jharkhand state alone for industrial purposes.

e.Use of CBM at Steel Plants

Blast furnace operations use metallurgical coke to produce most of the energy required to melt the iron ore to iron. Since coke is becoming increasingly expensive in the U.S., the steel industry is seeking low-capital options that reduce coke consumption, increase productivity and reduce operating costs. All blast furnaces in North America inject some type of supplement fuel, such as natural gas, coke oven gas, oils and tars, or coal to form additional carbon monoxide and hydrogen for combustion, and chemical reduction of iron-bearing materials into molten iron. Of these fuels, natural gas and pulverised coal are the most widely accepted for injection. Recent full-scale tests have shown that injecting natural gas into blast furnaces at the rate of 195.4 cubic meters per ton of hot metal can reduce coke consumption by 30% , and can increase iron-making capacity by 40%. Coal mine methane provides the same benefits as conventional natural gas, and could easily be substituted for, or mixed with, natural gas for blast furnace use as long as it meets gas quality requirements (low sulfur content and at least 94% methane). Injection of CBM in blast furnace of Bokaro Steel Plant will improve performance and can enhance its productivity.

f.CMM use in Methanol production

Methanol is a key component of many products, including MTBE (used in reformulated gasoline), methanol and gasoline blends (such as M 85 for flexible fuel vehicles), formaldehyde resins (widely used in the housing industry), and acetic acid, a major raw material in the chemical industry. Most of the world's production of methanol uses natural gas as a feedstock, which is also the most important cost component. No methanol producers have coalbed methane, but it is a potential alternative feedstock to fuel large methanol plants in areas that mine gassy coal. Smaller (11.4-15 million liters/year) mobile methanol plants used at off-shore oil rigs may be a potential option for use at coal mines. Gas quality should be at least 89% methane, up to 1% oxygen and up to 10% carbon dioxide.

g.Utilisation of Coal mine methane

Besides above utilization prospects, linkages of coal mine methane (CMM) produced as a result of degasification of coal mines in comparatively in smaller quantity through cross country pipe lines may not be economical and therefore can be utilized at mine sites itself.

## CARBON SEQUESTRATION

Carbon sequestration is a geo-engineering technique for the long-term storage of carbon dioxide or other forms of carbon, for the mitigation of global warming. Carbon dioxide is usually captured from the atmosphere through biological, chemical or physical processes. It has been proposed as a way to mitigate the accumulation of greenhouse gases in the atmosphere released by the burning of fossil fuels.

$CO_2$ may be captured as a pure by-product in processes related to petroleum refining or from flue gases from power generation. $CO_2$ sequestration can then be seen as being synonymous with the storage part of carbon capture and storage which refers to the large-scale, permanent artificial capture and sequestration of industrially-produced $CO_2$ using subsurface saline aquifers, reservoirs, ocean water, aging oil fields, or other carbon sinks.

Sequestration techniques are not instantaneous and when considering their efficacy, consideration has to be given to the fact that they will therefore be acting on future (not current) $CO_2$ levels. These levels are expected by the IPCC to be higher than today's.

Different techniques of carbon sequestration:

1.Biological Processes
a.Ocean iron fertilization
b.Ocean urea fertilisation

c.Forestry
d.Agriculture

i.Reducing emissions
ii.Enhancing carbon removal
e.Peat production
f.Ocean mixing

2.Physical Processes
a.Bio-char burial
b.BECCS
c.Biomass burial
d.Biomass ocean storage
e.Carbon capture and storage

3.Chemical techniques
a.Ocean basalt storage
b.Industrial use
c.Chemical scrubbers
d.Ocean acid neutralisation
e.Ocean hydrochloric acid removal

Carbon capture and storage (CCS) is a means of mitigating the contribution of fossil fuel emissions to global warming, based on capturing carbon dioxide ($CO_2$) from large point sources such as fossil fuel power plants, and store it away from atmosphere by different means. It can also be used to describe the scrubbing of $CO_2$ from ambient air as a geo-engineering technique.

CCS applied to a modern conventional power plant could reduce $CO_2$ emissions to the atmosphere by approximately 80-90% compared to a plant without CCS. Capturing and compressing $CO_2$ requires much energy and would increase the fuel needs of a coal-fired plant with CCS by 25%-40%. These and other system costs are estimated to increase the cost of energy from a new power plant with CCS by 21-91%.

The first large-scale $CO_2$ sequestration project (1996) is called Sleipner, and is located in the North Sea where Norway's Statoil Hydro strips carbon dioxide from natural gas with amine solvents and disposes of this carbon dioxide in a deep saline aquifer. In 2000, a coal-fueled synthetic natural gas plant in Beulah, North Dakota, became the world's first coal using plant to capture and store carbon dioxide.

$CO_2$ has been used extensively in enhanced crude oil recovery operations in the United States beginning in 1972. There are in excess of 10,000 $CO_2$ wells in the state of Texas alone. The gas comes in part from anthropogenic sources, but is principally from large naturally-occurring geologic formations of $CO_2$. It is transported to the oil-producing fields through a large network of over 5,000 kilometres of $CO_2$ pipelines. The use of $CO_2$ for enhanced oil recovery (EOR) methods in heavy oil reservoirs in the Western Canadian Sedimentary Basin.