

# CONTENTS

Page No.

## Geochemistry and Petrogenesis of Crustal and Mantle derived rocks

- 1 Age and tectono-magmatic setting of Abor Volcanics, Siang Window, Eastern Himalayan syntaxial area, India  
*S.K.Acharyya and Puspendu Saha*
- 2 Dharwar stratigraphy and tectonics in relation to the southern granulite terrain  
*M. Ramakrishnan*
- 3 Crustal evolution in the parts of Shyok Suture Zone an example from the Shyok valley  
*D. Rameshwar Rao and Megha M Daga*
- 4 Wide spread acid intrusive activity in Shillong Plateau, Northeast India- A case study from the Kaindoli granite pluton  
*J. Mallikharjuna Rao, M. Venkateswarlu and K.P. Sarma*
- 5 Metamorphic evolution of the contact aureole of the Jhirdandandi Pluton, Sonbhadra district, Mahakausal mobile belt, Central India  
*A.K.Srivastava, S.P.Singh, Gopendra Kumar and S.B.Dwivedi*
- 6 Archean cratons: their composition, formation and preservation- Examples from Dharwar craton  
*Manikyamba, C. and Robert Kerrich*
- 7 Suitability of Ratangarh Shale Formation as marker horizon In Rewa Group of Vindhyan Supergroup  
*G.V.S. Poornachandra Rao*
- 8 Physico-chemical Characteristics of Quaternary Sediments of Godavari River basin, Parbhani-Nanded District Maharashtra  
*Md. Babar, Ghute, B.B. and Chunchekar, R. V.*
- 9 Petrographical and Geochemical Studies of the Spinel Lherzolitic Ultramafics of the Manipur Ophiolite Melange Zone, NE India  
*Ch. Mangi Khuman and Soibam Ibotombi*
- 10 Geochemistry, Depositional Environment and Tectonic Setting of the Noamundi-Koira Banded Iron Formation (BIF), Singhbhum-Orissa Craton  
*Shabber Habib Alvi and Harit Priyadarshi*
- 11 Integrated Geophysical Studies on Chimakurti-Uppalapadu Meso-proterozoic gabbro-nepheline syenite plutons, Eastern Ghats Mobile Belt, India  
*S. K. G. Krishnamacharyulu*
- 12 Island Arc Magma Genesis : Implications on Basic Magmatism in Prakasam Igneous Province to the East of Cuddapah Basin, India  
*K.S.V.Subramanyam, V. Balaram, U.V.B. Reddy, M.Satyanarayanan, Parijat Roy, Sawant S.S, A. Keshav Krishna and D. Srinivasa Sarma*
- 13 The Miaskitic Alkaline rocks of the Kunavaram – Chinturu areas, Khammam District, Andhra Pradesh  
*R. Mallikarjuna Reddy and S. Srinivas Reddy*

- 14 Disequilibrium micro-textures in plagioclase from 'aa' lava of 1994-'95 eruption, Barren Island Volcano, NE Indian Ocean: Evidence of dynamic plumbing system  
*M.L.Renjith*
- 15 Geochemistry and Paleomagnetism of the Basalt of the Ophiolite suite in parts of Phek District, Nagaland  
*S.K. Patil<sup>1</sup>, Glenn T. Thong<sup>2</sup>, Watitemsu<sup>3</sup>, Temjenrenla<sup>2</sup>, B.V. Rao<sup>2</sup>*
- 16 Precision Geochemistry and Analytical Techniques for improving the genetic modelling of Indian Volcanogenic Massive Sulphide Deposits  
*D.V. Subba Rao, S.N.Charan and B.Sreenivas*
- 17 The occurrence of Pillows in Ultramafite rocks near Bhairongondanahalli Village, Hassan Dist, Karnataka.  
*P.V.Sunder Raju and K.V.Anjaiah*
- 18 Petrography and geochemistry of columnar flood basalts from Anantagiri Hills, Andhra Pradesh, India  
*Archana B. Kaotekwar, Charan S. N., Balaram V, Satyanarayanan. M and Keshav Krishna. A*
- 19 Rb-Sr and Pb-Pb geochronological studies on the granite gneiss of Kuilapal, Purulia-Bankura Midnapore District, West Bengal  
*D.V.L.N. Sastry, U.K.Pandey and B.K.Pandey*
- 20 Compositional tri-modality in continental flood basalts in Rajkot region, Western Deccan Volcanic Province, India : evidence for early stage basaltic fractionation and magma evolution  
*Chakradhar Chavan, K. Naga Raju ,S.S. Sawant , A Krishna, V. Balaram, S.N.Charan*
- 21 A note on the occurrence of S-Type granite in Manai-Pyrda sector along northwestern margin of Shillong Basin, West Khasi Hills district, Meghalaya.  
*H.S Rajaraman, P.Sahoo, Pradeep Pandey and K.Umamaheswar*
- 22 Geochemistry, Petrogenesis and Tectonic Setting of mafic and Ultramafic rocks in parts of the Bhavani Complex- South India  
*K. Anbarasu, Ali Mohammed Dar, V. Balaram, M. Satyanarayanan, D.V Subba Rao, S.N. Charan*
- 23 Geochemical Characterization of Mafic and Ultramafic rocks of the Mettupalaiyam Ultramafic Complex - South India Implication for crustal growth and evolution  
*Ali Mohammed Dar, K. Anbarasu, Akhtar R. Mir, V.Balaram, M. Satyanarayanan, D.V Subba Rao, S.N. Charan*

### **Exploration for Precious Metals**

- 24 Platinum-Group Elements in Understanding the Earth's Processes  
*V. Balaram*
- 25 Platinum-group element geochemistry and tectonic environment of ultramafic of Ikauna in Madawara Igneous Complex, Bundelkhand Massif, Central India  
*S.P.Singh, M.Satyanarayanan, V.Balaram, M. Ram Mohan and K.V.Anjaiah*

- 26 Geochemical Investigations on the petrological members of Gem-bearing terrins in parts of Arsiapatnam, Visakhapatnam district, Andhra Pradesh, India  
*P. Trinadha Rao*
- 27 Ultramafic -Mafic Cumulates, Chromitites and volcanic provinces as potential targets for PGE Exploration  
*M.V.Subba Rao*
- 28 Preparation of low and high-grade certified PGE geochemical reference materials from Baula-Nuasahi Complex, Orissa, India  
*Satyanarayanan M, Balaram V, Singh R.S, Nayak S.K, Jena M.S, Mohanty J.K, Das J.N, Hanumantha, R, Sawant S.S, Subramanyam K.S.V, Dasaram B, Parijat Roy, Kamala C.T, Krishna A.K, Anjaiah K.V, Ramesh S.L and Gupta P.K.*
- 29 Geochemistry and Origin of the Archean Anorthosites from Khammam Region, Andhra Pradesh  
*Parijat Roy, V. Balaram, D.V.Subba Rao and S.N.Charan*
- 30 Petrogenesis of mafic flows and dykes of Rewa, Eastern Deccan Volcanic Province: evidence from PGE and radiogenic isotopic abundances  
*Trisha Lala, A K Chaudhary and D K Paul*
- 31 Platinum Group Elements and other Toxic Elements Distribution and Concentrations in the Environment with an emphasis on Respirable Suspended Particulate Matter (RSPM) data of the Hyderabad City and Adjoining Industrial Areas  
*C.T.Kamala and V.Balaram*
- 32 Distribution of Trace elements in Plants and Soils from Chromite Mineralization of Byrapur, Hassan District, Karnataka, South India  
*L. Chandra Sekhar Reddy and K.V. Ramana Reddy*
- 33 Geochemical Studies on the Late Archean Black Shales of Chitradurga Schist Belt, Dharwar Craton, India: Implications for the Provenance and Metallogeny  
*Sariput Sawant, V.Balaram, D.V.Subba Rao, M.Satyanarayanan and K.V. Anjaiah*

#### **Geochemistry of Energy Resources: Atomic Minerals**

- 34 Uranium Exploration in India, Present status & Future Strategies  
*P.B.Maithani*
- 35 Rare Metal and Rare Earth Mineralization in Different Geological Environs of India  
*P.V.Ramesh Babu*
- 36 Peraluminous granites: Potential source for Uranium mineralization in Koppunuru area, Guntur district Andhra Pradesh  
*R.V.Singh, Shekhar Gupta, M.B. Verma, M.S.M.Deshpande, A.V. Jeyagopal, K. Umamaheswar and P.B. Maithani*
- 37 Lithostratigraphic and Radiometric Appraisal of Srisailam and Palnad sediments in Kottapullareddipuram–Achchammagunta–Rachchamallepadu area, Guntur district, Andhra Pradesh: A Stratigraphic Drilling Approach  
*Rahul Banerjee, N.K. Bahukhandi, M. Rahman, K.K. Achar, P.V. Ramesh Babu, P.S. Parihar and P.B. Maithani*

- 38 Geological and Geochemical studies along zone of albitisation from Rohil to Rambas in Khetri Sub Basin of North Delhi Fold Belt, India  
*M.K. Khandelwal, B.K. Tripathi, S.K. Sharma, C.L. Bhairam and K. Umamaheswar*
- 39 Mineralogical Characterization of Mine sample of Gogi Uranium Deposit, Karnataka, India  
*Asoori Latha, A.K.Sharma, Sohail Fahmi and K.Shiv Kumar*
- 40 Preliminary studies on geochronology and geochemistry of uraniferous granites from Chitrial area, Nalgonda District, Andhra Pradesh  
*K. Asha, G. Nagendra Babu, V.Madakkuruppan, B. K. Pandey and K.Shivkumar*
- 41 Separation of Zircon from the beach sand deposit of Srikurmam area, Srikakulam district, Andhra Pradesh- A case study  
*G.V.S.U. Rao, A.K. Sharma, S.T. Seshadrinath, Sohail Fahmi, Ch. William Prasad and B. Nagabhushanam*
- 42 Geochemistry of basement granites of koppugattu-bamanapalle sector in the northern margin of cuddapah basin – implications for unconformity related uranium mineralisation  
*K. K. Parashar\*, A. R. Mukundhan, S. J. Chavan, P. V. Ramesh Babu*
- 43 Geochemistry and Sr and Pb isotope systematics of Basement Granitoids from north and west of Palnad Sub-basin, Guntur and Nalgonda districts Andhra Pradesh  
*Rajiv Vimal, Rahul Banerjee, Shekhar Gupta, Veena Krishna, K.K. Achar, P.V. Ramesh Babu, P.S. Parihar and P.B. Maithani*
- 44 X-Ray Diffractometric and Electron Probe Micro analytical studies on Uraninite and Fergusonite associated with pegmatoids from Kullampatti, Salem District, Tamilnadu, India.  
*R. Viswanathan, R.P.Singh, V.Rajagopalan, A.K. Paul, Yamuna Singh and K. Mahendra Kumar*
- 45 Mineral chemistry of Radioactive and Associated phases from Neoproterozoic unconformity related uranium deposits from Koppunuru, Palnad sub-basin, Guntur district, Andhra Pradesh, India  
*A.K. Paul, V. Rajagopalan, K. Shivakumar and M. B. Verma*
- 46 Hydrogeochemical Exploration for Uranium : A Case Study of Baramkela–Saria–Ambabhona area, Raigarh District, Chhattisgarh  
*Rahul Banerjee, Rajeeva Ranjan and P.B. Maithani*
- 47 Petro-mineraphic study of oolitic pyrite in radioactive quartz arenite rocks of Phonda Group from Kallamwadi area, Kolhapur and Sindhudurg District, Maharashtra  
*K.Shobhita, S.Srinivasan, A.K.Paul, M.Nagaraju, K.ShivKumar, K.Umamaheshwar and P.B.Maithani*
- 48 Integrated interpretation of heliborne geophysical and remote sensing data to identify potential targets for uranium exploration in parts of North Delhi Fold Belt  
*A.K. Pathak, A. Goswami, G.V. Giridhar, A.M. Selvan and A. K. Chaturvedi*
- 49 An integrated geological, geophysical and geochemical approach to characterize circular Electro Magnetic anomaly, Bhima Basin, Karnataka  
*I.Patra, A. K. Chaturvedi, V. Ramesh Babu and P. K. Shrivastava*

- 50 Thematic integration of spatial data sets to delineate favourable zones for uranium exploration in Gangpur basin, India  
*M Sridhar, A. K. Chaturvedi, R. Murlidharan and P. K. Shrivastava*

### **Geochemistry of Energy Resources:Oil & Gas**

- 51 Hydrocarbon Generation Potential of Oligocene Coals from Dilli River Section of Upper Assam Basin  
*N. Mathur*
- 52 Application of Isotope Ratio Analysis of Natural Gas in Solving Oilfield Problem Related to Annular Pressure Buildup  
*N. Mathur*
- 53 Delineating Gas-hydrates: Future Major Potential Energy Resource of India  
*Kalachand Sain*
- 54 Investigations of hydrocarbon seepages in Himalayan Foothills using molecular and isotopic studies  
*H.C. Pande, Ashok Raina, Vartika Roy, R.K.Saxena, A.K.Mittal, Harvir Singh and R. R. Singh*
- 55 Petroleum System Modeling in Yanam shallow offshore area of KG Basin, India  
*A.K. Sinha, Vibha Prabhakar, Harvir Singh and R.R. Singh*
- 56 Light hydrocarbon geochemistry of oils/condensates of Kali-Kuthalam area, Cauvery Basin  
*Kusum Lata Pangtey, Manmohan Singh Bisht, Rashmi Anand, Hari Das, Shishir Kant Saxena, Adarsh Kumar Mittal and Ram Raj Singh*
- 57 Petroleum Geochemistry of Oils from New Exploratory Wells in Western Offshore Basin, India  
*Jyoti H. Ganjoo, A.K. Bhatnagar, R.K. Saxena and R.R. Singh*
- 58 Evidence of Microbial Anomalies for Hydrocarbon Exploration in Jamnagar Sub basin, Saurashtra, Gujarat, India  
*Rasheed, M.A. and Dayal A.M.*
- 59 Hydrocarbon microseepage prediction by Near-surface geochemistry for Petroleum exploration  
*S.K.Thadoju, J.Buragohain and H.C.Das*
- 60 Application of Adsorbed soil gas and microbial methods for detection of hydrocarbon microseepage in near surface soils of Krishna-Godavari Basin, Andhra Pradesh, India.  
*M. Lakshmi, M. A. Rasheed, T. Madhavi, M. S. Kalpana, D. J. Patil and A. M. Dayal*
- 61 Geochemical significance of petroleum Asphaltenes as maturity and source indicators  
*Manoj Kumar Sarmah*

### **Applied Geochemistry in Environmental Studies**

- 62 Sedimentology, Geochemistry and Paleosol Control of Arsenic pollution in the Bengal Delta Plain underground Aquifers  
*D.M.Banerjee*

- 63 Advanced Cost-Effective Surface Geochemical Techniques for Oil/Gas/Uranium Exploration, Environmental Assessments and Pipeline Monitoring – a Template for India  
*Paul Lafleur Gyvn Chandrasekharan and S.Rajender Rao*
- 64 Municipal Solid Waste - a potential latent resource for Non-conventional Energy  
*M. Vikram Reddy and S. Srikanth*
- 65 Latest trends in hydrogeochemical research in Indian perspective  
*K Surya Prakash Rao and A G S Reddy*
- 66 Heavy metal concentrations in Groundwaters of Chikalthana area of Aurangabad, India  
*Deshpande, S.M., Aher, K.R. and Bhatpude, A.A.*
- 67 Hydrogeochemistry of groundwater in Basara area of Adilabad district, Andhra Pradesh, India  
*A.Narsimha and V. Sudarshan*
- 68 Groundwater Potential Modelling in hard rock terrain through Remote Sensing and GIS: A case study from Pulivendula- Sanivaripalli, Kadapa District, Andhra Pradesh  
*V. Sunitha, J. Abdullah Khan, B.Muralidhara Reddy, and M.Ramakrishna Reddy*
- 69 A review of Radionuclide transport parameters of some important host rocks and soils in India and implication on nuclear waste disposal approaches  
*RK Bajpai*
- 70 Experimental Studies on Modifications in Sorption and Swelling properties of Heat and Radiation Treated Bentonite Clays, NW India  
*A.S.Pente, R. K.Bajpai, C.P. Kaushik, B.S.Tomar and Kanwar Raj*
- 71 Chemistry and Mineralogy of Soils as Influenced by Climate Change  
*RAJA.P*
- 72 Nuclear waste disposal – from the perspective of a geochemist  
*Pranesh Sengupta and G.K. Dey*
- 73 Environmental geochemistry of marine sediments Off Poombuhar, Southeast Coast of India  
*Judith D. Silva, S. Srinivasalu, M. P. Jonathan, P.D. Roy, K. Anandasabari and M. Jeevanandam*
- 74 Effective Treatment Technologies of Effluents - A case Study from Industrial belt, Hyderabad, India  
*R. Sridhara Rao and G. Gnyananath*
- 75 Endosulfan conspiracy is a “Global Problem” bird’s eye view  
*H. Kariyanna*
- 76 Hot spots of Lead pollution and impacts on the Bio-systems  
*H. Kariyanna*
- 77 Geochemistry of groundwater in and around magampeta barite deposit, Cuddapah district, Andhra Pradesh, India  
*K. Ashok, V. Sudarshan, and A. Ravi Kumar*

- 78 Geochemistry of groundwater in kalwakurthy area, mahabubnagar district of andhra pradesh with special reference to fluoride distribution  
*R. Sundaraiah, V. Sudarshan and M. Ramana Kumar*
- 79 Geochemistry of groundwater in devarakonda area, nalgonda district, Andhra pradesh, India  
*Madhusudhan Nalla, V. Sudarshan, and M. Ramana Kumar*

### **Analytical Techniques and Data Processing**

- 80 Role of Analytical Chemistry in Geochemical Applications  
*Tulsi Mukherjee*
- 81 Effect of grain size on WDXRFS analysis of Chlorite-biotite-schist sample from Narwapahar, Sighbhum district, Jharkand, India  
*V. Madakkaruppan, Chanchal Sarbajna and S.Nayak*
- 82 Determination of Arsenic, Antimony, Bismuth, Selenium and Tellurium in three in-house geochemical reference materials by flow injection or continuous flow-hydride generation-atomic absorption spectrometry  
*Chebrolu Rama Mohan Rao*
- 83 A simple economic and quantitative method for the removal of Uranium from Gogi Mine water using Powdered Red Brick  
*Usha Nathan, Bincy cyriac, G. N. Hegde, A. Premadas and A. K. Rai*
- 84 A simple, rapid and direct determination of silver in geological samples by graphite furnace atomic absorption spectrophotometer  
*Anitha Mary Thomas, A. Premadas and K. Satyanarayana*
- 85 ICP-MS determination of Rare-Earth Elements and Thorium in Uranium-Rich Geological Samples  
*V.Padmasubashini and K.Satyanarayana*
- 86 Microwave Assisted Determination of FeO in Tourmaline  
*M. Krishnakumar, M. Dheeraja, C. Phaneendra and Smeer Durani*
- 87 Determination of Trace Toxic elements in Plant samples by ICP-MS and GF-AASS  
*Nandakishore, V.Padmasubashini and A.V.Raghunadh*
- 88 Wavelength-dispersive x-ray fluorescence spectrometric determination of uranium and thorium in granitic rocks  
*S. Viswanathan, P.B. Maithani, and Yamuna Singh*

### **Annexure**

1. ISAG - The Long Journey 1993-2011
2. INSTITUTION OF MEDALS And NOMINATIONS
3. Nomination Proforma I for Medals
4. Nomination Proforma II for Medals
5. Nomination Proforma III for Medals
6. Application for Membership of ISAG

**GEOCHEMISTRY AND PETROGENESIS  
OF CRUSTAL AND  
MANTLE DERIVED ROCKS**



# AGE AND TECTONO-MAGMATIC SETTING OF ABOR VOLCANICS, SIANG WINDOW, EASTERN HIMALAYAN SYNTAXIAL AREA, INDIA

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## ABSTRACT

The Abor Volcanics are one of the oldest reported occurrences of basaltic rocks from the eastern Himalayan syntaxial area. The Late Paleozoic or late Paleocene - early Eocene are the two main contesting ages assigned to them. The former represents rift-related volcanism associated with the Gondwana basin initiation in the proto-Himalayan belt under tensile regime, whereas, the latter, contemporaneous to India-Asia collision, represents Himalayan foreland basin volcanism under convergent setting.

The Himalayan thrust packet at the Siang Dome, located south of the Eastern Himalayan Syntaxis represents a transverse antiformal duplex trending NW-NNW. The Siang Window at its core exposes the Abor volcanic rocks, the overlying volcani-sedimentary Yinkiong Formation and the underlying Miri Quartzite. These rocks are placed below the arched splay of MBT roof-thrust, which floors Proterozoic rocks.

The low grade protoquartzite and dolomite assemblage overriding the MBT is correlated to the Proterozoic Buxa Formation, whereas, the Miri Quartzite is mainly exposed at the core of the Siang Window. Calcareous quartzite or limestone from the contact zone of the the Miri Quartzite and the Abor Volcanics has often yielded a rich assemblage of larger foraminifera indicating Late Paleocene to Early Eocene age, whereas, the Yinkiong Formation contains foraminifera assemblage indicating Early to Mid Eocene age.

The volcanic rocks inter banded with Lower Permian Gondwana equivalent sediments exposed in Siang Window and further west are also correlated to the Abor Volcanics. This correlation is strengthened by the report of Permian Gondwana spores from some sectors of the Abor Volcanics. These possibly represent reworked and recycled elements, as reported from some areas in northeastern India.

Geochronological study has been carried out recently on the Abor volcanics and associated rocks (Liebke et al., 2011). A relatively fresh large basalt boulder from the Yamne river bed yielded Late Carboniferous ( $319 \pm 15$  Ma K-Ar, WR) age. Other basalt samples yielded  $87.2 \pm 1.3$  and  $24.9 \pm 0.4$  Ma ages, which possibly represent reset ages resulting from argon loss during alteration. Single grain Zircon Fission Track (ZFT) thermo-chronological study on the Yinkiong and Miri formations yielded well defined age clusters, indicating a post-Paleocene and post-Jurassic deposition age respectively. Thus the volcanic rocks intercalating or intruding them are not part of Late Palaeozoic sequence but represent latest Cretaceous to Tertiary event(s). The youngest age cluster of the Miri Quartzite at c.150 Ma does not support widely suggested Proterozoic to Permian age for the Miri Quartzite.

Probably, the major source of both Yinkiong and Miri sediments was located on the overriding Asian plate and /or Gangdese thrust belt. The Jurassic-Cretaceous thermal events retained in detrital zircon age spectra are clearly not connected to the Indian Plate. Liebke et al. (2011) inferred that volcanic bodies intruding the Miri or inter banded with the Yinkiong are clearly post Permian and latest

Cretaceous to early Tertiary in age. Thus the Abor Volcanics constitute volcanic rocks of more than one age as was postulated by some earlier workers.

The Abor Volcanics are porphyritic and aphyritic basaltic rocks. Plagioclase phenocryst are common in porphyritic type, but is replaced by alkali-feldspar in alkaline basalts. The groundmass of both consists of plagioclase microlites, clinopyroxene and partially altered glass.

Based on major element and limited trace element data, together with the inferred Permian age, the Abor Volcanics were inferred to represent within-plate 'rift valley' stage of the Tethyan ocean. Other workers based on trace- and RE- element data inferred continental volcanic setting for the Abor, comprising chemically coherent tholeiitic and alkaline volcanics. Based on late Paleocene to Early Eocene age, the Abor was inferred to be Himalayan foreland basin volcanics. Thus the inferred age of the Abor influenced interpretation on their petro-magmatic setting.

Geochemically studied samples earlier were restricted to southern exposed parts of the Abor volcanic rocks. Present synthesis includes geochemical data on our 10 earlier and 6 recently collected samples. The latter also cover its northern exposures. The Abor volcanic rocks mainly represent within-plate continental flood basalt. The abundances of some major-, large-ion lithophile- and some trace-elements from the Abor have been affected by alteration and post-crystalline oxidation. However, several trace- and RE- elements largely remained unaffected. On the basis of close match ratios of strongly incompatible elements, it is concluded that the Abor Volcanics correspond to a chemically coherent group of tholeiites with minor alkaline basalt components. Most of tholeiitic and alkaline basalts have been generated from sources having similar character. All the samples are enriched in incompatible elements indicating an enriched sub-continental lithospheric mantle source. The tholeiitic and alkaline basalts have been produced by different degrees of partial melting. The continental flood basalt was generated by extensive partial melting of the subcontinental mantle. The pattern of elemental variation has been further affected by low pressure fractional crystallization mainly involving olivine and plagioclase. On the other hand, Late Paleozoic basalt associated with Permian Gondwana and exposed along the MBT zone and correlated to the Abor Volcanics is generally alkaline.

Present study confirms presence of Late Paleozoic basalts from the Siang Window. The *in-situ* positions of these are not known but appear to be located close to the MBT roof-thrust. The foreland basin related Abor Volcanics possibly intruded along deep seated faults, some of which might have followed the weak zones of pre-existing Gondwana rift-related basins and the MBT. Thus, although unrelated in age and tectonic setting, both the late Paleozoic rift-related component of the Abor Volcanics suite and the Late Paleocene-Early Eocene aged Himalayan foreland basin component of the Abor Volcanics might be closely associated spatially in the MBT zone.

## Reference

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# DHARWAR STRATIGRAPHY AND TECTONICS IN RELATION TO THE SOUTHERN GRANULITE TERRAIN

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## ABSTRACT

Dharwar craton (DC) comprises two tectonic blocks called the Western Dharwar craton (WDC) and Eastern Dharwar craton (EDC). The dividing line between them is not a sharp line, but a transitional zone between the Chitradurga Shear Zone (CSZ) and the Closepet Granite. The regional stratigraphy of the craton is tabulated below:

Ga	WDC	EDC
2.4	Mafic dykes	
2.5-2.6	Granulite facies metamorphism	
2.6	Chitradurga, Arsikere Granites	Closepet Granite
2.6-2.7	Chitradurga Group	Kolar Group
2.7-2.8	Bababudan Group	Eastern Gneiss (2.7 Ga) (Dharwar Batholith)
~3.0	Peninsular Gneiss	—
3.1-3.3	Sargur Group	
3.3-3.4	Gorur Gneiss	Putative Basement Gneiss

Sargur Group consisting of ultramafic- mafic rocks (komatiites, layered complexes), pelitic schists, BIF, and minor quartzite-limestone, is invaded by TTG Gneiss with its diapiric trondhjemite-granodiorite plutons (Peninsular Gneiss) forming a large batholith in WDC. Subduction of the oceanic crust probably from the east caused the generation of continental arc batholiths (WDC), followed by accretion of a microcontinental arc (EDC) in the vicinity of the present location of Closepet Granite, to produce the Dharwar craton. The craton is overlain by the Dharwar Supergroup with its wide-spread but thin basal quartz-pebble conglomerate (QPC). The lower Bababudan Group is confined to the WDC, but continues in the transitional zone as a minor belt (Hagalvadi) to the east of Chitradurga schist belt, and as small screens (Yashwantanagar Formation) in the transitional Sandur schist belt. Bababudan Group, together with the basement gneiss, is rapidly uplifted and eroded, and followed upward by the deposition of the upper sequence of Chitradurga Group, with its basal polymict (Talya, Kaldurga) conglomerate. Chitradurga Group shows a spectacular facies change with the shelf facies assemblage (Vanivilas Sgp/ Subgroup) with its prominent BIF-MnF in the basin margin, graduating homotaxially into the Ingaldhal Volcanics comprising a large volcanic ensemble. This sequence is overlain by a thick greywacke pile (Ranibennur Sgp) in WDC. Ingaldhal Volcanics with thin, disrupted screens of Vanivilas Sgp together with a prominent Champion Gneiss unit (felsic volcanics, polymict conglomerate) comprise the entire greenstone sequence of EDC, called Kolar Group, which is equivalent of Chitradurga Group of WDC. The major Sandur schist belt is transitional in nature, having BIF-MnF and quartzite-limestone of Vanivilas Sgp (WDC) and the large volcanic sequence (with minor greywacke) of Kolar Group (EDC). The EDC is invaded by Granodiorite-Monzogranite-Granite (GMG) suite forming a calc-alkaline batholith.

In a recent comprehensive tectonic model of tectonic evolution of Dharwar craton, B.Chadwick, V.N.Vasudev and others visualized the accretion of Dharwar arc batholith, with its intra-arc greenstone belts (Kolar Group), on to the of back-arc continental foreland by oblique subduction of oceanic lithosphere to the WNW, along the sinistral transpressional Chitradurga shear zone. The lack of fore - arc sequence is a major problem in this model. D.Chardon, J.-J. Peucat and M.Jayananda propose an alternative non-uniformitarian sagduction model with plume-arc interaction in the DC. In minor modification of the accretion model, M.Ramakrishnan proposed that continental back arc of WDC accreted with easterly vergence with EDC to produce the continental arc batholith of EDC formed by closure of several parallel volcanic rifts (eastern greenstone belts). The Closepet Granite probably formed the stitching granite between the accreting terrains.

The Southern Granulite Terrain (SGT) consists of the deeper level granulite terrain of the Archaean Dharwar craton with an unbroken transition from the greenstone terrain in the north, called the Dharwar Granulite Belt; and the Neoproterozoic (Pan-African), granulite grade mobile belt called the Pandyan Mobile Belt. SGT is a misnomer since it amalgamates and straddles two starkly contrasting terrains of widely differing geology and age. DC and PMB are separated by two major shear zones, viz., Moyar-Bhavani-Attur shear zone (MBASZ) and Palghat-Cauvery shear zone (PCSZ). The intervening area between the shear zone ids called the Cauvery Shear System (CSS) or Cauvery Suture Zone. The CSS consists mainly of Archaean gneisses, charnockites, greenstone relics and tectonic slivers of PMB. PMB comprises GMG gneisses, charnockites, a large QCP suite (quartzite-carbonate-pelite) with minor mafic rocks and abundant Pan-African intrusions. The regional stratigraphy of PMB is as follows:

480-550 Ma	Pan-African Intrusions
~500-550 Ma	Granulite Facies Metamorphism
500-600 Ma	Charnockites, gneisses, leptynites, migmatites Southern Khondalite Group (Cheran Group)
700-800 Ma	Alkaline Rocks, carbonatites and granites
1700-2200 Ma	Putative basement gneisses

SGT is described by M.Santosh, T.R.K.Chetty, J. Collins and others as a suture zone that includes eclogites, ophiolites and high-pressure metamorphic assemblages, overprinted by UHT metamorphism and intruded by Pan- African plutons, during final continental collision. The Achankovil shear zone that divides that Madurai Block with swirling structural pattern from Trivandrum Block, which is straight belt is visualized as part of the earlier Pacific orogeny. This Pacific-Himalayan, Pan-African orogeny has closed the Mozambique Ocean during the assembly of Gondwana. This model is still under scrutiny, with new data pouring in from new field and laboratory investigations. The fascinating evolution of Dharwar craton and the Pandyan Mobile Belt is making this region a classical terrain of southern India ideal for future research.

# CRUSTAL EVOLUTION IN THE PARTS OF SHYOK SUTURE ZONE AN EXAMPLE FROM THE SHYOK VALLEY

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## ABSTRACT

The Shyok Suture Zone (SSZ) in northern Ladakh separates two distinct terranes, the southern continental margin of Eurasian Plate to north, and Ladakh magmatic arc to the south. It is a linear NW-SE trending zone that runs for about 250 km between Turtok in the west and Chushul in the east. The Shyok-Darbuk section, the studied area, the Shyok valley of the SSZ of eastern Ladakh, has distinctive lithostratigraphy and evolution history related to magmatism, metamorphism and crustal evolution and thus the geodynamics of the India-Eurasia convergence. Magmatism in this section of the crustal block spans from pre-collision subduction-related calc-alkaline orthogneiss to post-collision related leucogranites, involving anatexis of hybrid source of calc-alkaline orthogneisses and metasedimentary rocks. The goal of the present work includes the petrogenesis of rocks through geochemical studies, for understanding the process of crustal evolution. The geochemical data from the Shyok-Darbuk section can be also used to relate with the various phases of Ladakh and Karakoram arc magmatism for the overall understanding of mountain building process in the region.

The corridor of Shyok-Darbuk section includes an older phase of hornblende-biotite porphyritic granite, biotite leucogranite and a younger phase of garnet-muscovite-biotite leucogranite, and migmatites. The orthogneisses are porphyritic, medium to coarse grained calc-alkaline, titanite bearing hbl + bt granitoids. Field studies show that the orthogneiss have basic enclaves within it. The size and shape of enclave varies widely, ranging from 3-50 cm in width and more than a meter in length. The enclaves show sharp to diffusive contact with host orthogneiss. The calc-silicate rocks in the region have inter-bedded leucogranite bands within it, and generally contain grt + sc + hbl + cc + pl + qtz + spn. On the other hand the metapelites have grt + pl + qtz + sil/ky + bt ± ms ± kfs + ap + ep assemblage. Amphibolites and amphibolite schists are also not uncommon both in orthogneiss and leucogranites. The late phase granitoids Porphyritic Granites (PG), Coarse Leucogranites (CLG) show intrusion into hbl-bi orthogneiss, and also intrusive relations with one another. They are also intruded by a younger phase of leucogranites with or without garnet and tourmaline minerals (LG). The orthogneiss show chemical characteristics typical of Andean-type granitoids, while the geochemical studies of late phase granitoids viz. PG, CLG and LG suggest that they are derived from partial melting of subduction related lower crustal rocks, and the mafic enclaves show genetic relations with the host orthogneiss.

The main component of crustal evolution in the Shyok Suture Zone of Shyok-Darbuk section can be explained by two stage melting process involving the generation of orthogneiss with mafic enclaves, and temporal evolution towards increasingly more evolved felsic magmas during reworking processes. In the light of the geochemical evidence it is postulated that, (i) the early formed orthogneiss have originated from the mafic/intermediate magmatic products of continental-margin subduction related to a syn- to pre-collision arc setting of probably Eocene to Late-Cretaceous age; (ii) the *in-situ* partial melting of the precursor basement of early formed arc crust along with metasedimentary material

derived from wedge which had played a significant role in the evolution of post-collision Miocene felsic melts in the form of PG, CLG, LG, and associated pegmatite rocks, along with the generation of leucosomes in the migmatites. However, the correlation of the orthogneiss and leucogranites of Shyok-Darbuk corridor with Ladakh and Karakoram granitoids in general does not provide any conclusive relation with either, and is still a matter of debate, but is of importance for paleo-plate reconstructions.

## **WIDE SPREAD ACID INTRUSIVE ACTIVITY IN SHILLONG PLATEAU, NORTHEAST INDIA- A CASE STUDY FROM THE KAINDOI GRANITE PLUTON**

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### **ABSTRACT**

The Precambrian basement of Shillong Plateau represent an uplifted block consists of siliceous gneisses overlain by undeformed Proterozoic rocks of Shillong group. A number of discordant granitoids of various sizes and ages intrude the basement gneissic complex and Shillong group of sediments. Isotopic age data available on these intrusive granites range from 880- 480 Ma while the ages of basement gneisses vary from 1714 to 1150 Ma. Some of the important dated granite plutons in the Shillong Plateau are Kyrdem granite (479± 26 Ma), Songsak granite (500± 40 Ma), Myllem granite (607±13 Ma), Golpara granite (647±122 Ma), South Khasi granite (690 to 748 Ma), Rongjeng granite (788±21 Ma) and Sindhuli granite (881±39 Ma). The Nongpoh granite gneiss (1150±26 Ma) and Patharkhang granite gneiss (1714±44 Ma) represent the basement rocks. The granitic activity in the Shillong Plateau is thus restricted between 500- 880 Ma and the plutons have not suffered any post-emplacement tectonothermal events.

The granitic rocks are extensively studied during last few decades as they are most abundant rocks in the upper continental crust and closely connected with tectonics and geodynamics. The paper discusses the study on the isolated circular plug like intrusive granitic body emplaced in to the basement gneisses near Kaindoli village, SE of Shillong. The detail study of this granite reveals that it is unaltered, porphyritic type, consists of microcline, plagioclase, quartz and biotite as essential minerals and is similar to Myllem granite. Major and trace elemental data show variations within the pluton. The observed variation are SiO<sub>2</sub> (65-70 wt%), Al<sub>2</sub>O<sub>3</sub> (13.7-14.75 wt%), TiO<sub>2</sub> (0.5-0.9 wt%), Total iron (4.0-6.0 wt%) and alkalis (7-9wt%) and trace element ranges are Rb (162-283 ppm), Zr (44-150 ppm), Sr (130-278 ppm), Y (44-81 ppm), Nb (12-38 ppm), Ba (835- 1450 ppm) and total rare earth elements (REE) 223- 843 ppm. The Kaindoli granites are geologically and geochemically similar to Myllem granite and probably emplaced around 600 Ma. These granites might have derived from lower crustal rocks and fractionated REE patterns suggest partial melting of gneisses that gave rise to these granites.

# **METAMORPHIC EVOLUTION OF THE CONTACT AUREOLE OF THE JHIRGADANDI PLUTON, SONBHADRA DISTRICT, MAHAKAUSAL MOBILE BELT, CENTRAL INDIA**

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## **ABSTRACT**

The metamorphic evolution of the contact aureole around the Mesoproterozoic Jhirkadandi pluton in the eastern part of Parsoi Formation of Mahakoshal terrain, Central India represents the three distinct metamorphic aureoles/zones characterized by definite mineral assemblages. The Mesoproterozoic contact-metamorphic event produced the peak-metamorphic mineral assemblages Bt + Qtz + Ab + Sill ± Crd ± Grt ± Ms ± Kfs in the metapelites of inner aureole, Bt + Qtz + And + Mus + Kfs + Plag ± Crd ± Chl of middle aureole and Chl + mica + And + Alb + Qtz + Ept + Mt + Tourmaline in the outer aureole. The mineral chemistry, phase petrology and P-T condition of the aureoles have been studied on the basis of EPMA data. The estimated P-T conditions in the hornfelsic rocks near the contact with granitoids (inner aureole, 690°C/3.4 kbar), slightly away from the contact (middle aureole 580±15°C) and away the contact (outer aureole 487 ±30 °C). The emplacement of the Jhirkadandi pluton at shallow crustal levels was rarely accompanied by weak deformation of the metasediments (D<sub>2</sub>). During cooling and exhumation, the contact aureole was locally affected by deformation (D<sub>3</sub>) and retrograde metamorphism (M<sub>3</sub>) again under greenschist-facies conditions.

## **ARCHEAN CRATONS: THEIR COMPOSITION, FORMATION AND PRESERVATION-EXAMPLES FROM DHARWAR CRATON**

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## **ABSTRACT**

The Archean cratons having rich metal deposits are well preserved due to thick, buoyant and refractory continental lithospheric mantle. The Dharwar craton of southern peninsular India have excellent preservation of Archean greenstone belts ranging in age from 3.4 – 2.6 Ga interpreted as composite tectonostratigraphic terranes of accreted plume and convergent margin-derived magmatic sequences based on high-precision elemental data.

The mantle plume-related volcanic sequence include komatiites and komatiitic basalts, tholeiitic basalts having near-flat HREE patterns, are well preserved in the Sandur greenstone belt of Dharwar craton. Komatiites are the Al-undepleted variety, signifying melting in a mantle plume, above the garnet-peridotite facies at < 90 km. This association has been explained as komatiites being erupted from the hot core of a mantle plume, whereas, tholeiitic basalts represent melts of cooler ambient asthenospheric mantle entrained into the annulus of the plume. Tholeiitic basalts of Sandur belt are compositionally akin to those of the komatiite-basalt association of the Superior Province and Kambalda Terrane of the Yilgarn Craton which collectively are similar to basalts that dominate Phanerozoic intraoceanic plateaus such as Ontong-Java, Kerguelen, and Naru. High-Mg basalts are associated with alkaline basalts in Penakacherla greenstone terrane of Dharwar craton. High-Mg basalts are abundant in Archean terranes, likely reflecting melting of hotter ambient mantle whereas, alkaline basalts are rare in Archean greenstone terranes, except some documented in the 2.7 Ga Wawa belt. Interaction of plumes with lithospheric mantle has been evident through the elemental studies on few volcanic sequences of Archean greenstone terranes. Occurrence of Archean alkaline basalts reflect on subduction, recycling and incubation of Mesoarchean crust and its incorporation into the mantle source of a late Archean mantle plume. Consequently, some form of plate tectonics was operating from the Mesoarchean. Mantle sources have been established through the mantle array based on the Th/Yb versus Nb/Yb relationship. The komatiites, high Mg-basalts plot between NMORB to EMORB and alkaline basalts have OIB characteristics. Therefore, enriched and depleted mantle reservoirs have been established in the Archean mantle.

Some Recent and Phanerozoic intraoceanic arcs have a distinct type of magnesian volcanic flow, termed as boninite characterized by high Mg#, Cr, Co, and Ni contents, U-shaped REE patterns, negative anomalies at Nb, and elevated  $Al_2O_3/TiO_2$  ratios. Boninitic compositions have been documented from the Archean Abitibi terrane, Superior Province; Isua, Greenland; and Dharwar craton. The tholeiitic to calc-alkaline basalt-Mg-andesite-Nb enriched basalt-adakite association were first described from Cenozoic arcs has now been documented from numerous Neoproterozoic greenstone terranes of several cratons including the Gadwal greenstone terrane of Dharwar craton. Depleted and enriched basalt were identified from Hutti greenstone belt of Dharwar craton, likely represent a paired backarc and arc that are comparable to modern paired arc-back arc systems of the Southwest Pacific. Volcaniclastic turbidites studied from few greenstone belts also recorded diverse volcanism present in the greenstone belts. These diverse volcanic associations were assembled to give composite terranes in a subduction-accretion orogen at ~ 2.7 Ga, coevally with a global accretionary orogen at ~ 2.7 Ga, and associated orogenic gold mineralization. Archean lithospheric mantle, distinctive in being thick, refractory, and buoyant, formed complementary to the accreted plume and convergent margin terranes, as migrating arcs captured thick plume-plateaus, and the refractory, low-density, residue of plume melting coupled with accreted imbricated plume-arc crust. A contemporaneous example is capture of the Ontong Java plateau by the Solomon arc. The continental lithospheric mantle (CLM), which is thick and stable under all Archean cratons, is responsible for preservation of Archean crust.



# SUITABILITY OF RATANGARH SHALE FORMATION AS MARKER HORIZON IN REWA GROUP OF VINDHYAN SUPERGROUP

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## ABSTRACT

The Meso-Neoproterozoic Vindhyan basin in Central India is a large sedimentary basin occupying an area of 1,04,000 sq km, extending in the states of Bihar, Uttar Pradesh and Rajasthan with undisturbed and unmetamorphosed rock sequence. A number of sedimentary rock formations were investigated for their palaeomagnetic signatures that have thrown light with respect to reconstructions of palaeogeography and magnetostratigraphy during their deposition. Mostly sandstones and limestones of different groups were sampled and investigated. Vindhyan shale formations were never studied for palaeomagnetism as these are highly friable to sample either by field drilling or block sampling. For the first time, the Ratangarh Shale Formation of Rewa Group of Vindhyan Supergroup formations were collected by block sampling and subjected to palaeomagnetic study employing AF and thermal demagnetization techniques up to 100 mT and 680° C respectively. These shales are having high coercive forces of 70 mT and high blocking temperatures of 680°C, indicating the carrier mineral to be haematite that carries a stable remanence over long geological periods. A ChRM signature of  $D_m = 347^\circ$ ,  $I_m = +59^\circ$  ( $K = 23.84$ ,  $\alpha_{95} = 12.1^\circ$ ,  $N = 6$ ) corresponding to a VGP at  $\delta_p = 71.5^\circ$  N,  $L_p = 42.0^\circ$  E ( $\delta_p = 18.0^\circ$   $\delta_m = 13.5^\circ$ ) has been isolated from these shales resulting in a palaeolatitude ( $\delta_m$ ) of  $35^\circ$  N. This ChRM is identical with that of the Malani rhyolites that has been well constrained by Rb-Sr age of 771-751 Ma in the Indian geological and palaeomagnetic studies so far. The Ratangarh shale formation is highly reliable with its identity with Malani rhyolite VGP and being carried by high blocking temperature high coercive force magnetic mineral namely haematite. Hence, the Ratangarh shale, that is correlated with the Jhiri shale in several sub-basins, with highly reliable ChRM, can be considered as a marker horizon between 771-751 Ma in the Vindhyan Supergroup. The palaeolatitude of the Ratangarh shale formation is favourable for the occurrence of hydrocarbons within the Vindhyan basin because of its palaeoequatorial location during its deposition that has been confirmed by the drilling results by the Oil and Natural Gas Corporation (ONGC).

# **PHYSICO-CHEMICAL CHARACTERISTICS OF QUATERNARY SEDIMENTS OF GODAVARI RIVER BASIN, PARBHANI-NANDED DISTRICT MAHARASHTRA**

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## **ABSTRACT**

Godavari river valley is an important agricultural belt in Maharashtra state of India. The study area, Godavari river basin in Parbhani - Nanded districts is considered for the present study. The area belongs to semiarid and subtropical climate characterized by hot summer and the normal annual rainfall of 860.40 mm. Geologically, the entire study area is covered by Deccan Basalt formations comprising gently sloping to nearly horizontal lava flows. These flows have been considered to be a result of fissure type of lava eruption during late Cretaceous to early Eocene period. The types of basalt flows occurring in the area are compact basalt flow (aa type), vesicular-amygdaloidal basalt flows (pahoehoe type) as observed in the well sections. There is occurrence of Quaternary sediment along the river valley.

The physico-chemical characteristics of Quaternary geomorphic surfaces such as present floodplain, older alluvial plain and pediments are discussed. The physical characteristics studied included colour, texture, structure, consistency of soil and particle size distribution. Of these, colour, texture and structure of soil was studied and recorded in the field itself, at the time of sample collection. The last two were subsequently confirmed by the mechanical analysis of soil. Similarly chemical parameters like pH, EC, OC, CaCO<sub>3</sub> were determined from the selected samples to understand the characteristics of the sediments in relation to processes and their environment. To establish the true nature of sedimentation and processes involved, it was necessary to identify the different sedimentary facies. This identification helped in understanding the geomorphic processes operating in time and space.

## **PETROGRAPHICAL AND GEOCHEMICAL STUDIES OF THE SPINEL LHERZOLITIC ULTRAMAFICS OF THE MANIPUR OPHIOLITE MELANGE ZONE, NE INDIA**

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The ophiolitic peridotites of the Manipur Ophiolite Melange Zone can be broadly classified into two physically distinct groups. One type generally showing lighter olive green colour is almost wholly serpentinised with very intense shearing along closely spaced fractures having occasional well developed slickensides. The other type showing dark green colour is comparatively fresh with no closely spaced fractures. The field setting is that the less abundant and sporadic occurrence of less serpentinised group is generally found enclosed and protruding as blocks within the extensively serpentinised variety. The peridotitic serpentinites constitute much more than 90% of total ophiolitic sequence of the zone.

Melanocratic rocks in the hand specimens show good amount of large brownish phaneritic pyroxene crystals. The ultramafic rocks generally show xenoblastic granular texture in which the grain size is widely variable. And these ultramafic rocks are principally composed of serpentines derived from olivine, bastites, olivine, orthopyroxene, clinopyroxene, and primary and secondary spinels. Elongation and alignment are shown by the grains of orthopyroxene, clinopyroxene and primary spinel. The ultramafic rocks also show variable amounts of orthopyroxene grains exhibiting exsolved lamellae of clinopyroxene and vice versa. Modal proportions of these phases are: serpentine from olivine  $\pm$  relics of olivine, 62-78%; serpentine from orthopyroxene  $\pm$  relics of orthopyroxene, 13-26%; serpentine from clinopyroxene  $\pm$  relics of clinopyroxene, 0-8%; primary spinel, 1-4% and secondary spinel, 1-10%.

From the EPMA data, olivine is found to be  $Fo_{91}Fa_9$  where the ratio of  $MgO/(MgO + FeO)$  is found to be 0.845 and that of  $Mg/(Mg + Fe + Mn)$  is about 0.810. The composition of orthopyroxene is found to be of  $En_{88}-Fs_9-Wo_3$  while that of clinopyroxene is  $En_{56}-Fs_4-Wo_{40}$ . From the analysis data of spinel, the composition is computed to be of spinel series = 68%, magnetite series = 20% and chromite series = 12%.

Major oxides (XRF) data indicate that the  $MgO/(MgO + FeO)$  values of the ultramafic rocks of Manipur Ophiolite cluster around 0.82-0.84, with few exceptions whose values are less than 0.8. The average  $Al_2O_3$  content is about 1.60% while average  $100Cr/(Cr + Al)$  value is about 14.40. The rocks also have average 0.840%  $Na_2O$  and 0.056% K.

ICP (MS) data show that a number of trace elements except Ni and Cr have concentrations two or three orders of magnitude more than normal ophiolite peridotites. The REE's are also extremely enriched from those of the normal ophiolite ultramafics.

Exsolution lamellae of clinopyroxene in the orthorhombic host and vice versa indicate an earlier solid solution between Mg- and Ca- pyroxenes, which have been made failed on account of prolonged subjection to equilibrium conditions of lower temperature environment in such a way that situations are well below the solidus of the corresponding P-T phase diagram. From the modal proportions of olivine, orthopyroxene and clinopyroxene (considering no much effect of volume change of serpentine when converted to that of the original mineral phases), the ultramafic rocks of Manipur Ophiolite range from lherzolite to harzburgite. The olivine composition reflects less depleted nature of the ultramafic rocks of Manipur Ophiolite. Plotting the composition of orthopyroxene on the pyroxene quadrilateral reveals that the ultramafics of Manipur Ophiolite is very close to the field of metamorphic peridotite. When  $100Cr/(Cr + Al)$  in spinel is plotted against  $Al_2O_3$  weight percent of co-existing orthopyroxene, the ultramafic rocks of Manipur Ophiolite is found to be of Aluminium-spinel lherzolite. When  $Cr/(Cr + Al)$  and  $Mg/(Mg + Fe^{+2})$  ratios of spinel are plotted the ultramafic rocks of Manipur Ophiolite correspond to lherzolic fertile upper mantle material. The consistent value of the ratio of  $MgO/(MgO + FeO)$  indicates that, even though the different ultramafics had different proportions of olivine and orthopyroxene, their compositions were almost the same. The samples having values less than 0.8 of  $MgO/(MgO + FeO)$  ratio are those in which the modal proportions of secondary spinel are almost negligible. The lesser value of the ratio could be related to the loss of materials from the system on account of certain processes related with serpentinisation. The average  $Al_2O_3$  content of about 1.60% reflects higher proportion of clinopyroxene phase than that of normal ophiolitic harzburgite and dunite, and also that the source is more fertile. The extremely enriched  $Na_2O$  and K also indicate that the ultramafic rocks of Manipur Ophiolite are from a fertile source. When the major oxides' data are plotted in the AFM and ACM diagrams the rocks are pigeonholed in the metamorphic peridotite field. Trace element and REE concentrations are indicative of fertile sub-continental upper mantle origin.

# **GEOCHEMISTRY, DEPOSITIONAL ENVIRONMENT AND TECTONIC SETTING OF THE NOAMUNDI-KOIRA BANDED IRON FORMATION (BIF), SINGHBHUM-ORISSA CRATON**

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## **ABSTRACT**

In the Singhbhum-Orissa Craton, Banded Iron Formation (BIF)-hosted iron ore deposits and shale-hosted Mn-ore deposits form a Paleoproterozoic horse-shoe shaped synclinorium (referred to as Noamundi-Koira basin) on the western side of Mesoarchean Singhbhum Granitoid Complex. Metavolcanic rocks of Bonai Range occur as the lowermost formation of the Noamundi-Koira basin and at many places it conformably grades into Lower Shale Formation (LSF). The mineralogical and chemical characteristics of Bonai metavolcanic rocks such as absence of spinifex texture, calc-alkaline trend of magmatic differentiation, low Ti/Zr, Zr/Nb and high Zr/Y ratio, chondrite normalized flat to LREE enriched REE patterns and Primordial Mantle normalized zig-zag patterns of incompatible trace elements clearly indicate their origin as convergent margin or supra-subduction related volcanism.

LSF, devoid of Fe or Mn ore deposits, is represented by tuff and tuffaceous shale (-phyllite). Petrography reveals the pyroclastic texture of these rocks. Higher concentration of,  $K_2O$ ,  $TiO_2$ ,  $MgO$  and  $Al_2O_3$ , and small-scale primary structures attest their volcano-sedimentary affinity. The middle unit is about 250 meter thick BIF that conformably overlies the LSF. It also contains a very distinctive, several meter thick unit of granular iron formation. The geochemical and mineralogical characteristics suggest that massive, hard laminated, soft laminated ore and blue dust have a genetic lineage from Banded Hematite Jasper (BHJ). Magnetite was the principal iron oxide mineral, whose depositional history is preserved in BHJ, where it remains in the form of martite and hematite. The different textural relationships and field occurrences of iron ores show that combination of different processes rather than single one was responsible for the formation of different types of iron ores. Lower values of  $SiO_2$ ,  $Al_2O_3$ , REE, Co, Ni and Cu suggest input from hydrothermal activity. PASS-normalized REE concentrations show HREE enrichment with a positive Eu anomaly.

The Upper Shale Formation (USF), occurring in the centre of the Noamundi-Koira basin, is comprised of a mixed chemical-clastic sedimentary facies. It conformably overlies the BIF. The layered, lenticular, lateritoid and vein type Mn- ore bodies are associated with the USF. Composition of the USF and Mn- ore with widely variable  $Fe_2O_3$ , MnO, Ni and Cr concentrations reveal their respective manganese and ferruginous nature. High  $Al_2O_3$ , low  $MgO$ ,  $CaO$ ,  $Na_2O$ ,  $K_2O$  and a high chemical index of Alteration (CIA) of the USF (always more than 70) correspond to its observed kaolinite mineralogy.  $TiO_2$ ,  $P_2O_5$ , Ni and Cr correlate well with the  $Fe_2O_3$  suggesting their presence in the magnetite, hematite and ilmenite. The  $K_2O/Na_2O$ ,  $Al_2O_3/SiO_2$  ratio and trace element data indicate that USF was deposited in active continental margin setting.

# **INTEGRATED GEOPHYSICAL STUDIES ON CHIMAKURTI-UPPALAPADU MESO-PROTEROZOIC GABBRO-NEPHELINE SYENITE PLUTONS, EASTERN GHATS MOBILE BELT, INDIA**

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Chimakurti-Uppalapadu plutons represent an unusual clinopyroxenite-gabbro-anorthosite-ferrosyenite and nepheline syenite association in the Prakasam Province of the Eastern Ghats Mobile Belt, India. Both the plutons are intruded into the deep Precambrian continental crust composed of amphibolites, quartzites and khondalites. Geological and geochemical studies suggest that Chimakurti and Uppalapadu magmatic bodies are coeval but possibly derived from two contrasting magmas. The magmatic association of ferrosyenite in between these two contrasting plutonic bodies is another debating issue. In this paper we propose a novel rationale in solving this geological problem by using integrated geophysical approach using gravity and magnetic anomalies supported by density, magnetic susceptibility, and AMS studies.

Density and magnetic susceptibility show a wide variation among the lithologies and are correlated with changing mineral assemblages and abundances. The density and susceptibility values show conspicuous intra-pluton, inter-pluton and pluton-country rock contrast. The AMS results correlated with gravity and magnetic anomalies envisage the possible association of ferrosyenites in this unusual magmatic set-up.

The modeling and inversion of gravity and magnetic anomalies suggest distinct subsurface infrastructures for the Chimakurti and Uppalapadu plutons with a sharp rather than a gradational contact between them. The studies further envisage that the other exposed gabbro plutons are independent without a subsurface connection, and are formed along a possibly rift related fault zone. Gravity and magnetic modeling also revealed a sharp ferrosyenite-nepheline syenite contact and a gradational ferrosyenite-gabbro contact. This geophysical approach provides more clear understanding of the subsurface structure of the plutons and the magmatic processes associated with the Chimakurti-Uppalapadu plutons.

# ISLAND ARC MAGMA GENESIS : IMPLICATIONS ON BASIC MAGMATISM IN PRAKASAM IGNEOUS PROVINCE TO THE EAST OF CUDDAPAH BASIN, INDIA

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## ABSTRACT

Among many plutonic rocks occurring within the continental crust, the exposures of basic rocks on the earth's surface are found to be less abundant than others and are attributed as products of magma generated from partial melting of deep seated rocks due to local perturbations. The analogy of various occurrences of these plutonic basic rocks indicate that majority of them are intrusive into pre-existing rocks as new crustal material implying the role of later thermo-tectonic regimes which might have been responsible for newer additions to the crust. The dynamic processes, operating at deeper levels, of our earth causing certain "unscrupulous" events in addition to producing large volumes of molten material at specific locales. In the plate tectonic parlance, divergent and convergent plate margins are favourable sites where basic magmas are generated through rifts and arc systems in large volumes resulting in formation of all types of igneous rocks. All arc systems are unique and each can contribute to our understanding of subduction processes and modern day tectonics, not only the present day magmatic processes but also provides key solutions in interpreting palaeo island arc systems. A study of such rocks is undertaken belonging to the Prakasam Igneous Province located to the east of Cuddapah Basin, particularly from geochemical point of view, which proved to be unravelling the probable sites of origin, processes involved for the generation of melts, the nature of source rock and subsequent crystallization process.

The petrological studies carried out reveal that the grain size is coarse to medium with very well defined grain boundaries. Cumulus, hypidiomorphic-holohyaline and sub ophitic textures are shown by all the gabbroic rocks with dominant mineral assemblages of plagioclase feldspar, Cpx and occasional olivine, Opx, biotite, amphiboles and sphene. Exsolution features of magnetite lamellae are seen on Cpx and at places the Cpx alterations to hornblende also observed. Two episodes of crystallisation (early and late crystallization) of some minerals like plagioclase feldspar and Cpx are seen. SEM-EDS studies conducted on these samples revealed sub microscopic Mg-rich olivine (forsterite) crystals along the grain boundaries of Cpx.

Major oxide data show that the rocks are low to medium in SiO<sub>2</sub> (48-52%), low TiO<sub>2</sub> (0.2-0.6%) and low Na<sub>2</sub>O (0.9-1.8%), medium in Fe<sub>2</sub>O<sub>3</sub> (6-10%) and high in Al<sub>2</sub>O<sub>3</sub> (13-18%, average ~16%). SiO<sub>2</sub> against other major oxide plots indicating flat TiO<sub>2</sub> and Na<sub>2</sub>O trends, positive trend of CaO and negative trends of MgO and Al<sub>2</sub>O<sub>3</sub>. The plots against silica are found to be insignificant except MgO and Fe<sub>2</sub>O<sub>3</sub>. TAS (Fig.1, Total Alkalies vs. Silica, Middlemost, 1985) and AFM (Fig. 2, Irvine and Baragar, 1971) diagrams classifies that these rocks as tholeiitic gabbros. Harker diagrams show typical magmatic trends. The rocks under study can be classified as high alumina gabbroids with subordinate MgO content (average 7%).

Relative enrichment of Sr and Ba and depletion of Ni, Cr are characteristic features of lower crustal involvement in the magma processes. The positive Eu anomaly shows the role of plagioclase accumulation in these rocks, in agreement with their high Sr/LREE values (Fig.3 & 4). Fractionation and enrichment of LREE relative to HREE may be due to the predominance of clino-pyroxene and plagioclase mineralogy. The high LREE enrichment also imply the possibility of low degree of partial melting or LREE enriched melt as source (Wilson, 1989). Eu positive anomaly for these rocks indicates the cumulus nature of plagioclase in the melt and this is best evidenced in the photomicrographs of Boggulakonda and Pasupugallu plutons where as rest all samples recorded a flat or absence of Eu anomaly indicative of plagioclase in residue.

Petrogenesis of mantle derived magmatic rocks are commonly deduced from their geochemical and petrological characteristics.  $\text{CaO}/\text{Al}_2\text{O}_3$  and  $\text{CaO}/\text{TiO}_2$  ratios have an important significance in petrogenetic studies of basic rocks (Crawford and Cameron, 1985; Beccaluva and Serri, 1988). Majority of these basic rocks show  $\text{CaO}/\text{Al}_2\text{O}_3$  ratio less than chondrite value 0.9 (Sun and Mc Donough, 1989). The inverse relation existing between  $\text{CaO}/\text{TiO}_2$  and  $\text{CaO}/\text{Al}_2\text{O}_3$  vs. Mg# (Fig. 4 & 5) in the basic plutonic rocks reflect the fractionation of Cpx (Perfit et al 1980, Class et al 1994). Similar relationship also existing between Ni and Cr and Mg #, also suggests that the Cpx fractionation is in turn a controlling factor of Ni and Cr abundances. In closed a system, Cpx becomes a major fractionating phase only in more evolved MORB or above 10.5 Kbar pressure where it replaces olivine as a liquidus phase (Walker et al 1979; Wilkinson, 1982) or when magma mixing occurs in open system chambers (Dungan and Rhodes, 1978 ; Walker et al 1979). According to Wilkinson (1982), the crystallisation sequence of magnesian MORB indicate that at low pressures (<5 Kbar) clinopyroxene does not crystallise until the separation of significant olivine and plagioclase occurs (sometimes after approximately 50% crystallisation). Further, Ti vs V plot after Shervais (1982), classify these rocks as island arc tholeiites. These important geochemical parameters studied point towards a subduction setting where such pressure fractionation of Cpx around 10.5 kbars or more is available.

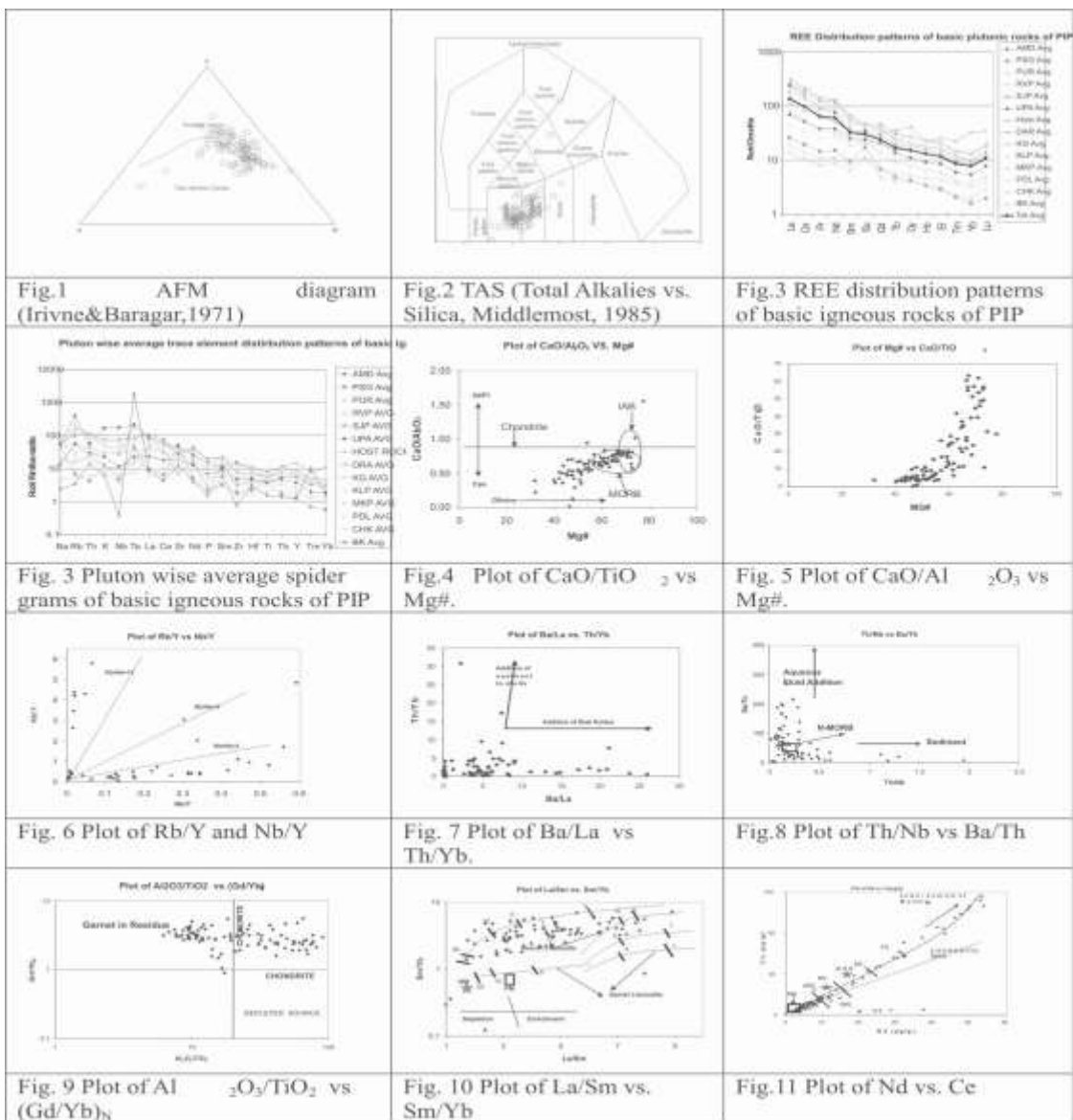
Rb/Y and Nb/Y ratios (Fig.6) are studied for an understating on the mantle sources modified by slab melts by circulating slab fluids. Rb/Y, Nb/Y, Th/Zr, Ba/Nb and Ba/Th ratios are generally low for mantle derived melts unless there is a metasomatic effect by circulating fluids or slab derived fluids (Zhao and Zhao, 2007). The studies on these trace element ratios indicate the following; i) melt related enrichment ii) addition of slab fluids, and iii) aqueous fluid addition.

The matasomatic agents and influx from the subducted slab may be further finger printed by the trace element ratios such as Ba/La, Th/Yb, La/Yb and La/Nb. The plot of Ba/La vs. Th/Yb is essentially an LILE / REE and most immobile Th/Yb indicate the fluid activity for which Ba (LILE is more soluble than REE and Th, Yb) concentrations are indicative. In the basic rocks variable Ba/La are observed where as Th/Yb are constant. This is indicative of addition of slab fluids into the source region of the mantle. Conversely variable Ba/Th ratios observed when plotted against Th/Nb, showing constant ratios, indicating there by aqueous fluid addition, further substantiate the slab derived, subduction related, fluid induced metasomatism for LILE enrichment (Fretzdorff et al. 2002).

Incompatible trace element ratios such as La/Sm and Sm/Yb,  $(\text{Gb}/\text{Yb})_N$ ,  $\text{Al}_2\text{O}_3/\text{TiO}_2$  may be successfully employed to decipher the extent of melting, depth of melting and zone of melting in the mantle region. The high ratios of La/Sm (~4-6) are indicative of lesser to moderate degree of partial melting, but the very low ratios of La/Sm (~0.1-0.6) of Boggulakonda samples may be resultant of high degree of partial melting. Sm/Yb ratios (~0.2-6) are indicative of melting along the transitions of

garnet lherzolites – spinel lherzolites. This analogy may be explained based on the behaviour of Sm and Yb which are not affected by fractional crystallisation but depth sensitive and especially Yb is garnet controlled. Hence, it can be said that the smaller degree of partial melts generated in garnet lherzolite zone of mantle are responsible for the observed low to moderate ratios of Sm/Yb and LREE enrichment. A plot of  $(Gd/Yb)_N$  vs  $Al_2O_3/TiO_2$  further support the theory of garnet in residue during lower degree of partial mantle melting. Based on the Eu-negative anomalies depicted by some of these basic plutonic rocks, it can be inferred that plagioclase is at residuum at a lesser degree of partial melting or during initial stages of melting. With progression of further melting in plagioclase lherzolite depth zone of mantle, plagioclase slowly and progressively accumulated into the melt and thus contributed flat and positive Eu-anomalies Wilkinson (1982).

On the basis of geochemistry, it is evidenced, significant metasomatism of the mantle in the source region. It is hence likely that slightest difference in basic pluton chemistry reflect differences in depth of melting, zone of melting and also extent of melting, which can be related to either variable thickness of the descending slab or degree of metasomatism in a subduction tectonic setting resulting magmatism in an island arc fashion.





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## THE MIASKITIC ALKALINE ROCKS OF THE KUNAVARAM – CHINTURU AREAS, KHAMMAM DISTRICT, ANDHRA PRADESH

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### ABSTRACT

Alkaline gneisses marked by deformation are found emplaced at various locations in the recently demarcated Bastar alkaline province, the biggest body among them is located at Kunavaram along with a satellite body at Chinturu both in the Khammam district of Andhra Pradesh. While the major rock types being hornblende nepheline syenite and biotite nepheline syenite at Kunavaram, the Chinturu body is overwhelmingly composed of biotite nepheline syenite. Syenites constitute a subordinate component in both these belts. It is customary to distinguish alkaline rocks especially the nepheline syenites as agpaitic and miaskitic types depending on the Molecular proportion  $[K_2O + Na_2O]/Al_2O_3$  which is generally denoted as the agpaitic index .If the index is below unity the rock is miaskitic and in

case of the index exceeding one then the rock is Agpaitic. The agpaitic rocks therefore assume a peralkaline character unlike the miaskitic ones.

In the typical bivalent diagram depicting  $Al_2O_3$  vs  $Na_2O + K_2O$  in the Kunavaram-Chinturu alkaline rocks, it is most striking to find all the plots fall in the  $Al_2O_3$  field below the unity line, without any exception in the triangular diagram  $SiO_2 - Al_2O_3 - Na_2O + K_2O$  again all the rocks show clustering in the  $Al_2O_3$  field, reinforcing the miaskitic character of these rocks. In the  $Na_2O$  vs  $K_2O$  plot, all these rocks indicate  $K_2O > Na_2O$ . Although syenites are also plotted along with nepheline syenites in all these diagrams it has to be emphasized here that these two rock units are not genetically linked. Even then the syenites too in these two belts behave similar to nepheline syenites as far as  $Na_2O / K_2O$  is concerned. From the above depiction it is clear that the Kunavaram-Chinturu nepheline syenites and syenites come under miaskitic and not under peralkaline category.

## **DISEQUILIBRIUM MICRO-TEXTURES IN PLAGIOCLASE FROM ‘AA’ LAVA OF 1994-‘95 ERUPTION, BARREN ISLAND VOLCANO, NE INDIAN OCEAN: EVIDENCE OF DYNAMIC PLUMBING SYSTEM**

**M.L.RENJITH**

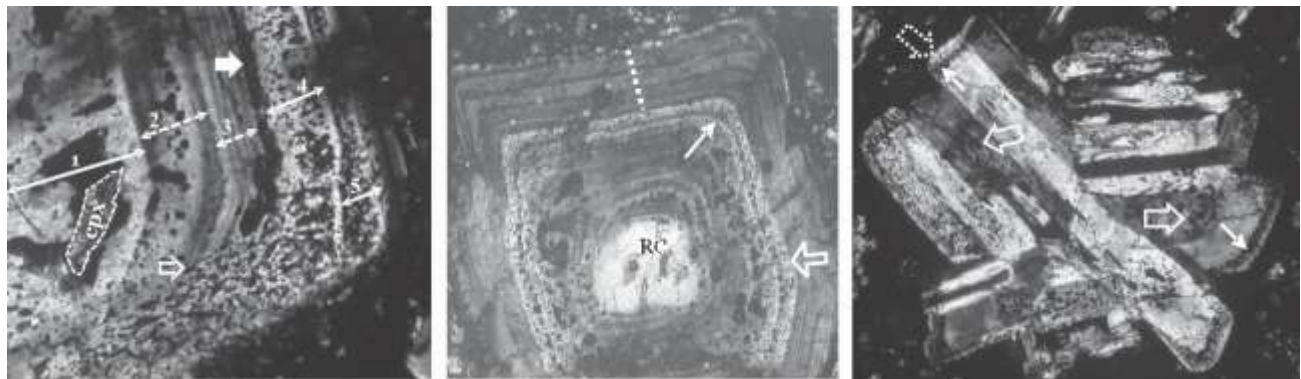
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### **ABSTRACT**

Barren Island Volcano (BIV), an active subduction-related volcano in the Andaman Sea, NE Indian Ocean, falls within the northern extension of Sumatra volcanic chain formed by northeastward oblique subduction of Indo-Australian oceanic plate beneath the Southeast Asian plate. BIV witnessed three major volcanic activity: i) a pre-historic eruption predate the year 1787; ii) between the year 1787 and 1832 and iii) from the year 1991 to 2009 four stages of eruption during the year 1991, 1994-‘95, 2005-‘06 and 2008-‘09 (e.g., Sheth, et al., 2009). The erupted products consist of aa lava flows, tephra fallout, lahars and surge deposits and have HAB and basaltic-andesites (rarely andesite) in composition. In the studied aa lava of 1994-‘95 eruption, plagioclase, an ambiguous phase, found as large (>4mm), smaller (<4mm) and microlite in sizes, exhibit wide range of disequilibrium micro-textures which record the crystallization dynamics. Large crystals often show isolated or interconnected coarse-sieve (CS) morphology at their core region (Fig.1a). They are the glass inclusions behave like opaque and give porous appearance to these crystal regions. Akin to CS there are closely spaced, uniformly distributed, very fine-size melt inclusions (fine-sieves; FS) occur as multiple zones in smaller grains or along the fringes of larger grains or overprinted on fine-scale growth zones (Fig.1). Both CS and FS occur as discrete regions in a grain. Fine-scale oscillatory zones (FOZ) are the set of 5-15 individual compositional zones, often found in smaller crystals (Fig.1b) and outer rim of larger plagioclase. Each zone has less than 4 $\mu$  thick. There are upto five FOZ-sets, separated by drastic change in composition (optical difference) or FS zone or major resorption surfaces observed from a grain. Their individual growth zones often show curved corners and wavy rather than straight at the margins. Within the FOZ synneusis of plagioclase laths are frequent. In many grains CS, FS, FOZ and resorption features are found together in a grain (Fig. 1a). Apart from their resorption-regrowth features plagioclase

are also exhibit unique morphological habits. A few to several plagioclase crystals interlocked as glomerocrysts which is typified by CS morphologies in their individual grains and FOZ or thin zone of FS running along their outer margin (Fig.1c). In addition, H-shaped outer skeletal envelopes in the smaller grains known as swallow-tailed crystals; microlites of less than a few micron size set in the groundmass along with mafic phases and glass; and broken crystal showing both euhedral and rugged grain margin are also significant plagioclase habits in these aa lava.

The above textures record the dynamic crystallization processes. The generated magma has undergone extensive crystallization of plagioclase at deeper magma chamber in a stable magmatic environment and then ascent to a chamber at shallow depth. While ascending decompression increases the  $p_{\text{H}_2\text{O}}$  of the system and cause partial dissolution of plagioclase as preserved as CS morphology (e.g., Nelson and Montana, 1992). At the shallow chamber, newly brought crystals and pre-existing crystals have undergone dynamic crystallization via reheating-regrowth under a convective self-mixing environment. Such dynamic condition favour the closely spaced grains with CS morphology to get attached together to form glomerocrysts (e.g., Hogan 1993). Hotter Ca-rich magma brought by each recharge event reheated the pre-existed crystals and cause partial dissolution as FS morphology (e.g., Tsuchiyama, 1985). Multiple FS in a grain imply repeated recharge events. Convection transport the crystals across the thermal or compositional gradients within the chamber. This has fluctuated the equilibria at the crystal-melt interface and cause rhythmic FOZ (e.g., Ginibre et al., 2002). Dissolution features like resorption/wavy surfaces and curved corners within the FOZ discard their kinetic diffusion controlled growth and imply the repetitive dissolution-regrowth events. During convection synnesis of plagioclase laths within FOZ was frequent (e.g., Vance, 1969). Syneruption process experience super cooling or an increase in the liquidus temperature due to water exsolution or vesiculation induced by magma decompression cause pervasive development of microlites (Castro and Mercer, 2004) and swallow tailed ('H'-shaped) morphology in plagioclase (e.g., Viccaro et al., 2010). While areal eruption the decompression blew apart the phenocrysts (broken crystals) which carry inclusions vesicle-rich melt entrapped at high pressures (e.g., Best and Christiansen, 1997). The erupted product of 1994-95 aa lava constitute of various physical mixtures of melts, genetically related crystals and xenocryst (e.g., Luhr and Haldar, 2006). The above new evidences of disequilibrium textures strongly support that crystal-rich magma from the deeper source is brought a shallow chamber where they thoroughly mix with pre-existing magma like a self mixing environment. This recharge event might be a repeated process which enhance convective recycling, degassing and finally violent explosion to produce varying population of plagioclase with disequilibrium textures in total volume of lava erupted during this period.



(RC) and FOZ overprinted with FS morphology (hollow arrow). Note that curved zone corners and wavy zone margins. [c] A glomerocryst showing CS morphology at the centre (hollow arrow) and FS morphology running along the grain fringe (thin arrow).

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## **GEOCHEMISTRY AND PALEOMAGNETISM OF THE BASALT OF THE OPHIOLITE SUITE IN PARTS OF PHEK DISTRICT, NAGALAND**

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## **ABSTRACT**

The ophiolite belt in Nagaland occurs along the Indo-Myanmar border where it is tectonically sandwiched between low grade greenschists of the Nimi Formation on the east and flysch sediments of the Disang Group on the west. In this belt serpentinites and volcanics predominate. These volcanics include basalt, basaltic andesite, hyaloclastites, and pyroclastics. These are associated with dismembered

bodies of peridotite, dunite, harzburgite, lherzolite, etc. Some of the basalts are altered to spilite. The basalts are closely associated with radiolarian chert and limestone. They exhibit relatively poor fractionation of REE with almost flat chondrite-normalised REE patterns. LREE fractionation ( $La_N/Sm_N=0.51-1.40$ ) and that of HREE ( $Gd_N/Yb_N=0.83-2.26$ ) is negligible. Eu-anomalies are not prominent ( $Eu/Eu^*=0.39-1.11$ ) indicating negligible role of plagioclase fractionation in the petrogenesis of these basalts. Their geochemistry indicates their derivation from mantle sources similar to E-MORB and emplacement as ocean floor tholeiites in a back-arc basin near a plate margin. Palaeomagnetic studies on 19 oriented block samples are carried out to isolate ChRM directions using thermal and AF demagnetizations. The mean NRM intensity and magnetic susceptibilities found are  $6.45 \times 10^{-3}$  A/m and  $70.38 \times 10^{-5}$  SI units respectively. Out of the 19 block samples studied only two samples yielded statistically significant ChRM directions indicating that the age of the basalts are  $70 \pm 5$  Ma.

## **PRECISION GEOCHEMISTRY AND ANALYTICAL TECHNIQUES FOR IMPROVING THE GENETIC MODELLING OF INDIAN VOLCANOGENIC MASSIVE SULPHIDE DEPOSITS**

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### **ABSTRACT**

Major advances in analytical technology have occurred. Most notably, has been the introduction of the fourth and fifth generation inductively coupled plasma emission mass spectrometer (ICP-MS) and MC-ICP-MS, Stable isotope analysis of S, O, Cu, Zn and Fe and as well as new sample introduction technologies such as insitu major and trace element analysis of ore minerals and host rocks using the EPMA and SEM-EDS. Integration of the above mentioned high precision analytical data may lead to a better understanding of the Indian Volcanogenic Massive Sulphide Deposits (VMS). In the present work, an attempt has been made to utilize the trace and REE data to discriminate between barren and mineralized VMS deposits from Ambaji and Deri in South Delhi Fold belt. Massive, stratiform zinc-lead-copper ores occur at Ambaji and Deri located ~8km apart in Banaskantha district of Gujarat and Sirohi district of Rajasthan respectively. The Ambaji–Deri mineralized zone occurs in arkosic sediments to quartz wackes, metamorphosed to paragneisses, and biotite-quartz schist interlayer with concordant bodies of amphibolites (Deb, 1980). The Zn-Pb-Cu ores are concentrated in lensoid bodies. The trace element compositions of these host rocks and ores are characterized by the higher concentration of Pb, Cu, Zn and Co and moderate concentration of HFSE. Recently acquired Sulphur Analyzer system at NGRI determines the total sulphur content of these analyzed mineralized samples. Their Chondrite normalized REE patterns exhibit light REE enrichment  $(La/Sm)_N$ , strong negative Eu anomalies and flat to enriched HREE patterns ( $Gd/Yb_N=2.79$ ). Negative Eu anomalies are characteristic of these hydrothermal altered zone samples. Gale et al (1997) examined the applicability of using REE determined by ICP-MS for VMS exploration. In REE Chondrite plots, both stratigraphy and proximity to mineralization were clearly defined. In part, the Eu signature strength was found to be integral in defining hanging wall versus footwall and distal versus proximal in several examined deposits. The

observed strong negative Eu anomaly/Eu depletion in the Ambaji-Deri VMS ores is attributed that Eu may be leached out of footwall rocks in the hottest part of the hydrothermal system. A Chondrite normalized plot would reflect this Eu depletion. This Eu may be precipitated in the exhalative horizon proximal to these deposits. Consequently the chondrite normalized plot would reflect this Eu enrichment. This positive Eu anomaly often becomes weaker as one becomes more distal to the deposit. This provides a potential vectoring device for the exploration geologist. In addition, the trace element ratios such as Zn: Cu, Cu/Cu + Zn and Zn/Zn + Pb in VMS deposits can be used to decipher the intra deposit correlations and genetic modelling aspects. The non-traditional stable isotopes especially of transition metals, Cu, Fe and Zn reveal the subtle details of fractionation processes associated with exhalations or precipitation such as temperature of exhalations etc and as well as to understand the nature of redox sensitive environments. The other stable isotope compositions of S, C and O may throw light on the nature and origin of hydrothermal fluids. The insitu major and trace element analysis of ore minerals & host rocks using EPMA and CHIME dating of Zircons and monazite reveal the metamorphic P-T history and P-T-t paths. Integration of geology, petrography, Ore petrology, and high precision geochemical analysis inclusive of isotopes with that of geophysical characteristics may lead to a better understanding and characterization of the VMS deposits.

## **THE OCCURRENCE OF PILLOWS IN ULTRAMAFITE ROCKS NEAR BHAIROGONDANAHALLI VILLAGE, HASSAN DIST, KARNATAKA.**

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### **ABSTRACT**

The reconnaissance survey for platinum-group elements in mafic-ultramafic rocks, around Bairogondanahalli village ( #2241), NW of Arsikere in Hassan district revealed an outcrop with pillows typically measuring 0.85 x 0.3m, separated by fine rims of vesicular cavities at the rims of the pillows, signifying the oozing process. The outcrop trends N 320° and dips 75° west. One of the pillows shows fish eye structure, while other pillows are elongated. The presence of multiple-ring structures are common among shallow water pillows with diameter larger than 1m, eg. Oamaru in NewZealand, Columbian plateau (USA), and elsewhere. The multiple occurrences of pillows are formed by the condensation of exsolved water. When water condenses, due to the pressure difference between the interior and exterior, a pillow is created. Due to pressure differences the pillows often show buckling and thrusts. So the presence of multiple pillows structure is characteristic of shallow-water pillow lava. These types of ultramafite bearing intrusive complex and pillowed and nodular extrusive komatiitic ultramafic rocks in the northern parts of Arsikere, constituting Nuggihalli schist belt in northward and SE margin of Shimoga schist belt bring an additional information on mantle witnesses. The pillows are unusual in meta ultramafites . Several field observations with both intrusive and extrusive mechanisms are presented in this paper.

# PETROGRAPHY AND GEOCHEMISTRY OF COLUMNAR FLOOD BASALTS FROM ANANTAGIRI HILLS, ANDHRA PRADESH, INDIA

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## ABSTRACT

The Cretaceous age Deccan flood basalts of Anantagiri Hills near Vikarabad represented by six lava flow units occur as relatively less weathered basalts and partially lateritised rocks (Dutt, 1970). Formation of columnar joints with vesicular tops in the Anantagiri Hills is the most conspicuous feature in these basalt flow units. These six flow units, comprising a total exposed thickness of ~ 350-400 meters, exhibiting cooling joints representing primary columnar volcanic structures, enable division of individual flow units into three well defined zones namely: Lower Colonnade Zone (LCZ); Middle Entablature Zone (MEZ) and Upper Colonnade Zone (UCZ) grading upwards into a 5-10 m thick laterite cover. The columns in the UCZ are Vertical thick and five sided, the MEZ with a vesicular top and separating the UCZ and the LCZ displays four sided intersecting, fanning and fragmented columns, while the underlying LEZ also with a vesicular top has four to five sided vertical columns. These basalts are medium to coarse grained showing intersertal, and rare porphyritic textures. They are essentially composed of plagioclase feldspar, clinopyroxene,  $\pm$  olivine, Ti-magnetite, glass and zeolite group minerals. Preliminary geochemical data on Anantagiri flow units show that they are tholeiitic basalts having  $\text{SiO}_2$  ranging from 47.51 to 50.06 wt% and  $\text{Al}_2\text{O}_3$  from 12.28 to 13.81 wt%. These basalts show a mild affinity towards basaltic andesite on the TAS ( $\text{Na}_2\text{O}+\text{K}_2\text{O}$  vs.  $\text{SiO}_2$ ) diagram. On the Al-Fe+Ti-Mg ternary plot these basalts plot in the iron rich tholeiitic field nearer to the high-Mg tholeiitic field. The major and trace element signatures of the tholeiitic basalt are nearly similar to that of the Ambenali Formation basalts (Western DVP) with minor variations, suggesting continuation of the Ambenali Formation in the SE Deccan Volcanic Province. REE plots for these basalts define a nearly flat pattern with mild LREE enrichment and negligible negative Eu anomaly. Primitive mantle normalized multielement distribution patterns exhibited by these basalt flow units show a mild LREE, LILE trough, positive Ba, Nb and Pb peaks and negative anomalies for K, Sr and P that are in similarity with plume type CFB'S. Geochemical signatures shown by these tholeiitic basalt flow units suggest that the precursor to these high Fe-Ti-PCFB melts was probably generated by low degree partial melting of an enriched mantle source.

# RB-SR AND PB-PB GEOCHRONOLOGICAL STUDIES ON THE GRANITE GNEISS OF KUILAPAL, PURULIA-BANKURA MIDNAPORE DISTRICT, WEST BENGAL

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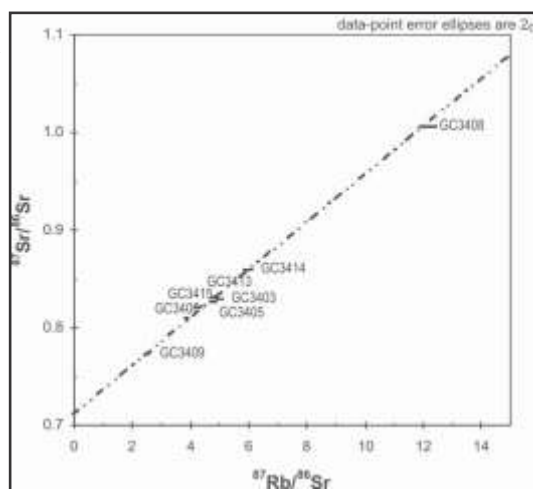
## ABSTRACT

The number of younger granite plutons intruding the Singhbhum Mobile Belt(SMB) surrounding the Singhbhum-Orissa Craton, viz. Kuilapal granite on the East, Mayurbhanj granite, Soda granite, Arkasoni granite, Chakradharpur granite gneiss and Tamper kola granite on the west. Of these Kuilapal granite body is the largest. Besides small granite bodies intruding the low-grade meta sediments and meta volcanics which occur north of the Dalma volcanic belt. Petrographic and geochemical characters of the minor granite bodies south of Dalma volcanics are similar to those of Kuilapal granite. which is inferred to have been produced by shallow-level fractional crystallisation of a crustally derived granodiorite melt. Dominance of xenoliths in the Kuilapal granite suggest large-scale assimilation of crustal rocks (1).

The radiometric ages vis-a-vis isotope geochemistry of the various granitoid plutons occurring within the mobile belt were used to constrain the evolutionary history of the SMB supracrustals. The Singhbhum Shear Zone which marks the boundary of the SMB with Singhbhum-Orissa Craton, shows multiple reactivation, the oldest being at ~3.09Ga. Further phases of granite plutonism and/or shearing and mineralisation have been reported along this shear zone occurred in Palaeo-to Mesoproterozoic periods at ~2.2, 1.8, 1.6-1.5, 1.4 and 1.0 Ga respectively (2).

The present work pertains to the Rb-Sr and Pb-Pb whole rock geochronological studies on the Kuilapal granite, which are intrusive into the metasediments of Singhbhum group in the external tectonic setup of north Singhbhum Mobile Belt. Fourteen samples were collected, finely powdered to form the homogenised representative which were processed further. The dissolution of the rock samples carried out in a class-100 clean chemical laboratory, followed by the elemental separation using ion-exchange chromatography(3). The separated pure fractions of the elements were analysed on VG354 Thermal Ionisation Mass spectrometer for their isotopic ratios following the procedure described elsewhere (4).

The Rb-Sr data on ten samples define an isochron age of  $1792 \pm 98$  Ma, with an initial  $^{87}\text{Sr}/^{86}\text{Sr}$  of  $0.7064 \pm 0.0069$  (MSWD = 13). The Pb isotopic data on these samples define a Pb-Pb isochron age of  $1863 \pm 80$ Ma (MSWD = 11.3) with a model  $\mu_1$  value of  $8.53 \pm 0.27$ . Both the Rb-Sr and the Pb-Pb ages are in agreement within the limits of experimental errors. Since the  $^{87}\text{Sr}/^{86}\text{Sr}$  initial ratio and model  $\mu_1$  value are higher than the contemporary mantle





sources, the data indicate involvement of enriched crustal sources. This age obtained on Kuilapal granite can be taken as the age of one of those periods of reactivation which occurred during Palaeo-to Mesoproterozoic periods.

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## COMPOSITIONAL TRI-MODALITY IN CONTINENTAL FLOOD BASALTS IN RAJKOT REGION, WESTERN DECCAN VOLCANIC PROVINCE, INDIA : EVIDENCE FOR EARLY STAGE BASALTIC FRACTIONATION AND MAGMA EVOLUTION

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### ABSTRACT

Most of the Deccan Volcanic Province basalts represent residual liquids dominated by plagioclase fractionation, but the basalts from Barambore, Chotila and Lodhika areas of Rajkot region in Western Gujarat exhibit early stages of fractionation dominated by clinopyroxene and olivine where plagioclase is negligible. They are sub-divided into three groups (I, II and III) based on distinct textural and geochemical characteristics. Significant variations in major oxides (SiO<sub>2</sub>, TiO<sub>2</sub>, FeO, MgO and CaO), compatible (Ni, Cr and Co) and incompatible elements (Zr, Nb, Ta, Y and REE) are utilized in deciphering their petrogenesis. Group-III basalts exhibit higher average values of Mg# (0.59), MgO (9.94 wt %), FeO (10.88 wt %), CaO (10.87 wt %), TiO<sub>2</sub> (1.96 wt %) and Ni (54-72 ppm) when compared with group-I and group-II basalts. Melts of group- III basalts are considered to be the parental liquid from which the highly evolved group-I and group-II basalts were derived by fractional crystallization. The observed geochemical variation in the Deccan basalts of Rajkot region is suggested to reflect different degrees of early stage fractional crystallization dominated by olivine+ clinopyroxene ± orthopyroxene fractionation at relatively deeper levels.

# A NOTE ON THE OCCURRENCE OF S-TYPE GRANITE IN MANAI-PYRDA SECTOR ALONG NORTHWESTERN MARGIN OF SHILLONG BASIN, WEST KHASI HILLS DISTRICT, MEGHALAYA.

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## ABSTRACT

Meghalaya Plateau is known for the Neoproterozoic granites such as South Khasi Batholith, Myllem etc. They are grey, porphyritic, I type and indicates age range of 757 to 479 Ma. However, the hypidiomorphic variants occurring in the gneissic complex are different by means of field setting, mineralogy, chemistry and age; is hereafter referred as 'Older granite'. An elongated body of such older granite showing pink colour is exposed within the gneissic complex in northwest margin of Shillong Basin, Meghalaya. They exhibit gradational contact with the gneissic complex / metasediments of Tyrsad Formation and show NE-SW trending foliation in Pyrda-Nongliput and Manai sections. This granite also contains xenoliths (restite) of muscovite-biotite schist and biotite gneiss.

The older granites (n=8) have analysed SiO<sub>2</sub> (70.9-77.1%), Al<sub>2</sub>O<sub>3</sub> (12.36-16.11%), K<sub>2</sub>O (4.41-5.51%), Na<sub>2</sub>O (3.45 to 4.96%) and CaO (0.33-0.66). The high K<sub>2</sub>O/Na<sub>2</sub>O ratio (1.04-1.46) indicating the potassic nature of older granite. Further, they have shown abundance of Rb (av. 170.35 ppm), Ba (av.193.25 ppm) and Sr (av.9.40 ppm) similar to low Ca granite. The granite exhibits highly differentiated nature (Differentiation index: 91-96), which is also corroborated by sample plots in strongly differentiated field in Rb-Ba-Sr diagram. In CaO-Na<sub>2</sub>O-K<sub>2</sub>O diagram, the samples plot in the quartz monzonite-adamellite field whereas in K<sub>2</sub>O vs Na<sub>2</sub>O diagram, they occupy granite to adamellite field. SiO<sub>2</sub> vs A/CNK plot and A/CNK vs A/NK variation diagrams reveal the S- type, peraluminous nature of these granite, which is further substantiated by the presence of normative corundum (0.41 to 3.27). In addition, the sedimentary parentage for older granite is evidenced by (i) relict gneissic foliation, (ii) xenoliths of muscovite-biotite schist and (iii) presence of sillimanite. Melt of near minimum composition appears to have been emplaced between 670° and 685°C (at p<sub>H<sub>2</sub>O</sub> 5kb) to give rise to the older granite as inferred from the normative Ab-An-Or ternary system.

# **GEOCHEMISTRY, PETROGENESIS AND TECTONIC SETTING OF MAFIC AND ULTRAMAFIC ROCKS IN PARTS OF THE BHAVANI COMPLEX- SOUTH INDIA**

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## **ABSTRACT**

The southern granulite terrain (SGT) consists of a series of crustal blocks delineated by crust penetrating shear zones. One among them is the east-west trending Bhavani shear zone (BSZ) which is located between Moyar-Bhavani lineament (M-B) in the north and the Palghat-Cauvery lineament (P-Ca) in the south. The Bhavani complex, emplaced in to the rocks of Sathyamangalam group contains the numerous gabbroic bodies in association with the pyroxenites. The gabbroic rocks exhibit banded structures with alternating leucocratic and melanocratic bands. The ultramafic-mafic association of Bhavani Complex occurs as dismembered sequence. Major, trace, and rare earth element (REE) geochemistry of the gabbro and pyroxenites collected from well exposed outcrops near Odhimalai and Thenkalmalai areas of this complex are presented and their petrogenetic significance is discussed.

The geochemical signatures of the gabbro and pyroxenites show a significant variation in major and trace element concentration. The pyroxenites show SiO<sub>2</sub> composition ranging from 49.6-55.5%, Al<sub>2</sub>O<sub>3</sub> from 6-13.6%, MgO from 3.6-14.3%, CaO from 8.4-15.5% and TiO<sub>2</sub> from 0.24-1.7% while average composition of SiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub>, MgO, CaO and TiO<sub>2</sub> in gabbro varies (in %) from 49.9-58, 9.4-13, 7.4-13.1, 9-13.4 and 0.26-0.54 respectively. The CaO-Al<sub>2</sub>O<sub>3</sub> relationship of both pyroxenites and gabbros shows their trend towards primordial mantle. Bulk composition/whole rock analyses indicate that the magma type is tholeiitic but trending towards a calc-alkaline.

Total rare earth element ("REE) content varies in a limited range and exhibits limited REE fractionation in both LREE and HREE. The pyroxenite sample shows Negative Eu-anomalies with slight enrichment of HREE. The studied samples are enriched in large ion lithophile elements with depleted high field strength (HFS) elements. (La/Yb)<sub>cn</sub> and (La/Sm)<sub>cn</sub> values, suggest the arc setting environment for the studied samples. PM- normalized Th/Nb and Rb/Nb ratios of the studied samples supports their derivation from non plume source.

# **GEOCHEMICAL CHARACTERIZATION OF MAFIC AND ULTRAMAFIC ROCKS OF THE METTUPPALAIYAM ULTRAMAFIC COMPLEX - SOUTH INDIA IMPLICATION FOR CRUSTAL GROWTH AND EVOLUTION**

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## **ABSTRACT**

The ~2.5 Ga mafic and ultramafic rocks occurring around the Punjai Puliampatti area of Mettuppalaiyam Ultramafic Complex have been studied for their field, petrographic, and geochemical (major, trace and rare earth element) signatures. The area is represented by dismembered sequence of pyroxenite, garnetiferous gabbro, and gabbroic anorthosite. These litho units occur as tightly folded ENE-WSW to E-W trending linear bodies within the amphibolite facies gneisses. Petrographic studies from the pyroxenite and gabbro samples reveal that the rock is medium to coarse grained, and is essentially made up of Ortho and Clino pyroxenes with subhedral crystals of amphibole. The opaques are mostly magnetite which occurs as discrete grains along the grain boundaries as well as along cleavage/fracture planes of pyroxenes /amphiboles.

Bulk composition/whole rock analyses indicate that the magma type is tholeiitic but trending towards a calc-alkaline. The pyroxenite sample shows slight Negative Eu-anomalies where as the gabbro displays flat trend with limited REE fractionation. The studied samples are enriched in large ion lithophile elements with depleted high field strength (HFS) elements. (La/Yb)<sub>cn</sub> and (La/Sm)<sub>cn</sub> values, suggest the arc setting environment for the studied samples. PM- normalized Th/Nb and Rb/Nb ratios of the studied samples supports their derivation from non plume source. In the Ce versus Nd diagram, the selected samples occupy the place around the 10% partial melting of PM, which indicates that the source of the studied samples was enriched in light rare earth elements (LREE) before melting or the magmas were contaminated before fractional crystallization.

**EXPLORATION  
FOR PRECIOUS  
METALS**

# PLATINUM-GROUP ELEMENTS IN UNDERSTANDING THE EARTH'S PROCESSES

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## Introduction

Platinum-group elements (PGEs: Ru, Rh, Pd, Os, Ir, Pt), Au and Re are highly siderophile elements (HSE) that were largely concentrated in the Earth's core shortly after planetary accretion. HSE concentrations in the mantle are too high (by several orders of magnitude) to be in equilibrium with metallic core. The mantle is also the ultimate source for most economic-grade PGE deposits. Determining average source composition and the minerals controlling the HSE budget are essential issues for modelling the HSE contents of mantle-derived magmas that may yield PGE deposits (Lorand, et al.2010; Maier, 2005; Naldrett, 2004). As PGE are so depleted in the Earth's crust, they can serve as important tracers for addition of extraterrestrial material, such as cosmic dust or meteorites at large impact craters. The PGE have different melting points that range from 3050°C for Os to 1555°C for Pd and can undergo fractionation during melting of the mantle, which makes them important tracers of various mantle melt processes. In the upper mantle, PGE appear to be hosted predominantly by interstitial sulphide minerals whereas they are more important hosts for PGE in the lower mantle in the form of alloys.

## Meteoritic Origin of PGE in Earth

Very recently Willbold et al. (2011) came up with a theory that 20 billion tons of staggering meteorite matter, including gold and PGE, slammed into the earth during the 200 million year long shower which struck the Earth 650 million years after its formation. Therefore, modern rock must have come from a meteorite shower which proves that today's gold and platinum deposits came from outer space. The puzzling presence of precious metals in Earth's mantle and crust may be explained once the mysteries of Earth's formation, dating back to 4.5 billion years ago, are solved. As magma cooled down and denser material sank towards the core of the planet, the iron-loving gold should have retreated toward the core and left barely any trace on the surface. Maier et al. (2009) also suggested a similar origin for PGE in the Earth. According to him, early Archaean komatiites recorded the signal of PGE depletion in the lower mantle, resulting from core formation. This signal diminished with time owing to progressive mixing-in to the deep mantle of PGE-enriched cosmic material that the Earth accreted as the 'late veneer' during the Early Archaean (4.5–3.8 Ga ago) meteorite bombardment.

## The origin of PGE deposits in layered mafic intrusions

Large layered mafic intrusions are one of the major sources for PGE. They also represent the primary evidence for fractional crystallization, a process in which molten rocks solidify by the crystallization of a series of different minerals. As the minerals crystallize, they are removed from the

melt which results in rock layers of different chemical or mineralogical composition that gives rise to stratiform PGE deposits (e.g., Merensky Reef in the Bushveld complex, South Africa). Studies have been initiated at NGRI in collaboration with other organizations to identify similar and other such occurrences in different parts of India (Balaram, 2006; Singh et al 2010, Berdnikov, 2010, Singh et al. 2011).

### **Chondrite-normalized PGE and Au distribution patterns**

The elemental abundances in C1 chondrites are believed to be the best available indication of cosmic abundances (Naldrett and Duke, 1980). When concentrations of PGE and Au normalized on the basis of the elemental abundances in type 1 carbonaceous chondrite (C1), are plotted against these elements in the order of their melting points, provide patterns that are much more regular than those that would be obtained for the un-normalized data. These chondrite-normalized PGE and Au distribution patterns provide information on the redistribution of elements within the deposits after emplacement of the sulfide liquid by processes such as fractional crystallization, immiscible sulphide segregation, and diffusion of elements in response to thermal gradient and hydrothermal activity.

### **PGE in marine geochemical studies**

Hydrogenous ferromanganese crusts are considered to grow by direct accumulation or precipitation of colloidal metal oxides from near bottom sea water. The supply of iron and manganese is strongly related to environmental factors such as biological productivity in the surface layer of the ocean and concentration of oxygen in the water column, etc. Due to low growth rates of a few millimeters per 1 Ma, ferromanganese crusts/nodules contain a detailed long-time record of changes in bottom water currents and the chemistry of the surrounding sea water during the past. Changes in sea water chemistry recorded in the marine sediments can provide information on the climatic changes in the past. Co-crust samples from Afanasy Nikitin Sea Mount in the central equatorial Indian Ocean contained very high concentrations of PGE (“PGE ranges from 1055 – 1955 ng/g). The strong enrichment of Pt (up to 1 $\mu$ g/g) relative to the other PGE and its positive correlations with Ce and Co demonstrated a common link for the high concentrations of all three elements. Several studies indicated that a surface oxidation of seawater Pt (II) to Pt (IV) by Mn (and possibly Fe) oxide is involved in the extreme enrichment of Pt in ferromanganese crusts (Balaram et al 2006; Banakar et al, 2007).

### **Iridium anomaly**

Apart from the economic importance of PGE & Au, which make them important exploration targets, their distinct geochemical properties make PGE as powerful tracer tool in probing planetary formations and to unfold the mysteries of core – mantle – crustal processes. Their concentrations also serve as excellent finger prints of extra-terrestrial input because these elements are several-fold enriched in meteorites compared to crustal rocks. Iridium particularly played an important role in studies linking the impact of an extraterrestrial object to the mass extinctions at the K-T boundary. Mass extinction events that punctuate Earth’s history are still enigmatic. High iridium concentrations in Cretaceous/Tertiary boundary clays have been linked to an extraterrestrial impact from an iridium-rich asteroid or large meteorite ~ 65 million years ago. Because iridium is abundant in meteorites (and in the earth’s

mantle), but rare in crustal rocks, it was proposed that the earth had been struck by a large (10 km diameter) chondritic (with character of stony meteorites) asteroid or meteorite. It was further suggested that this impact caused the ejection of a vast amount of dust that stayed in the atmosphere for about 6 months, resulting in the blotting out of the Sun's rays with consequent cessation of photosynthesis, breakdown of food chains, and the extinction of 70% of all life forms on earth, including the dinosaurs (Brooks, 1987). Other evidence in favor of the occurrence of such an impact has been provided by the detection of shocked quartz grains originating from impact and of amorphous carbon particles similar to soot, derived presumably from worldwide wildfires at that time. The physicist Luis Alvarez and his co-workers were the first to link the extinction to an impact event based on the observation that iridium is much more abundant in meteorites than it is on Earth. This theory was later substantiated by other evidences, including the eventual discovery of the impact crater, known as Chicxulub, on the Yucatan Peninsula in Mexico. In India, Anjar basalts provide unique opportunity for studying the relation of Deccan volcanism to the K-T boundary. The iridium content of Anjar basalts is high in a particular flow, F-2 which is the highest value (178 pg/g) observed in Deccan Traps so far. However, since alkali basalts form only a small fraction of Deccan Traps, their contribution to the iridium inventory at K-T boundary may be insignificant and its main source may be related to a bolide impact (Shukla et al. 2001). Thierry (2011) reported high iridium concentrations (up to 12 ng/g) in Meghalaya K-T boundary (Personal communications).

## Isotopic studies

Os has seven naturally occurring isotopes whereas Re has two, of which  $^{187}\text{Re}$  is radioactive and decays slowly via  $\beta$  decay to  $^{187}\text{Os}$ . Thus  $^{187}\text{Re}$ - $^{187}\text{Os}$  isobaric pair, recognized as a useful chronometer for both geochemistry and cosmochemistry (half-life for the decay is  $4.16 \times 10^{10}$  years), offers a unique opportunity for the direct dating of sulfides deposits and also studying genesis of ore deposits of PGE. In addition, osmium isotopic data, typically expressed in terms of  $^{187}\text{Os}/^{186}\text{Os}$ , which ranges from about 1 in mantle and meteoritic materials up to 30 in rocks of the crust, are being applied to solve questions of mantle composition, mantle - crust interaction etc. A long-standing debate in geology has been the relative roles played by the Earth's crust and mantle in generating the geochemical signatures of large igneous provinces (LIPs), and their influence in formation of mineral deposits in magmatic systems. Layered intrusions are central for addressing these issues, because they record periods of magmatic activity intimately associated with LIPs, and generally host precious metal mineralization within the system. Application of the Re-Os isotope system to these problems has allowed effective discrimination of crustal and mantle signatures, because Re and Os track the behavior of PGE with Re and Au collectively.

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# PLATINUM-GROUP ELEMENT GEOCHEMISTRY AND TECTONIC ENVIRONMENT OF ULTRAMAFIC ROCKS OF IKAUNA IN MADAWARA IGNEOUS COMPLEX, BUNDELKHAND MASSIF, CENTRAL INDIA

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## ABSTRACT

The Bundelkhand Craton is one of the Archean protocontinental nuclei in Peninsular India on which not much information on tectonic setting, evolutionary history and petrogenetic processes is available. The ultramafic rocks of Ikauna are relatively low in SiO<sub>2</sub> (42-48 wt%) and very low in Al<sub>2</sub>O<sub>3</sub> (0.09–1.88 wt%), CaO (0.20–1.60 wt%) and TiO<sub>2</sub> (< 1 wt%), and high in MgO (37.7 to 42.3 wt%). Cr and Ni are extremely high that ranges from 3000 to 6000 ppm and 1500 to 4000 ppm respectively. These rocks are dominated by coarse grained cumulates of olivine and occasionally with pyroxenes where medium to fine grained platinum group minerals (PGMs) including other precious metal and chromite occur as disseminated grains in the inter-granular spaces of olivine cumulates and pyroxenes. Compositionally, these rocks are variably evolved between peridotite and pyroxenite, and are of orogenic peridotite to mantle peridotite type. The variations in the REE fractionation, and other chemical features indicate magma derivation at moderate depths from high degree of partial melting of depleted mantle.

Concentrations of PGE and Au of the ultramafics samples from the Madawara complex, Bundelkhand are reported in ppb: Ir 8-23, Ru 17-300, Rh 0.08 -0.14, Pt 23-277, Pd 12-142 and Au 24-127. The primary mantle-normalized PGE distribution patterns reveal “swallow type” curve, with enrichment in Ru, Pt, Pd in comparison with Ir, Rh, and are similar to those of harzburgite in Pyrenees. The overall PGE abundances of ultramafics (upto 800 ppb, average more than 400 ppb) are higher than the averages of MORB and OIB and similar to ultramafics of orogenic peridotites. These rocks are enriched in the PGE but the mineralization of PGE is mainly confined into olivine websterites and is related to their concentration in late stage of cooling. The lithological assemblages and geochemical signature suggest the formation of these rocks within a subduction zone setting.

# **GEOCHEMICAL INVESTIGATIONS ON THE PETROLOGICAL MEMBERS OF GEM-BEARING TERRAINS IN PARTS OF NARSIPATNAM, VISAKHAPATNAM DISTRICT, ANDHRA PRADESH, INDIA**

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## **ABSTRACT**

Visakhapatnam district of Andhra Pradesh, India forms an important segment of Eastern Ghats Mobile Belt (EGMB) comprising invaluable resources, especially gem-minerals. The study area in parts of Narsipatnam comprise khondalite, charnockite, quartzite, pyroxene granulite, leptynite and pegmatite. The precious and semi-precious stones of Alexandrite, Chrysoberyl (cat's eye), Tourmaline, Sillimanite, Garnet, Zircon and a variety of quartz group are known to occur in these terrains at Narsipatnam – Paderu agency region. The gemstones occur in the primary and secondary stages.

Samples of the host rocks and associated gemstones were analysed for their major and minor elemental concentrations. A few of the selected samples were processed for X-Ray diffraction analysis. The geochemical affinities and the differentiation patterns are presented in the paper. Invaluable gem minerals are found in association with the Khondalite suite of rocks, as per their geochemical evaluation.

## **ULTRAMAFIC -MAFIC CUMULATES, CHROMITITES AND VOLCANIC PROVINCES AS POTENTIAL TARGETS FOR PGE EXPLORATION**

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## **ABSTRACT**

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 PGM 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) in them. PGE being siderophile elements occur mostly in the mafic-ultramafic 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 from these lithologies. Another area of interest for PGE exploration could be the mafic-ultramafic 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 that 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 will 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 and in 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.

## **PREPARATION OF LOW AND HIGH-GRADE CERTIFIED PGE GEOCHEMICAL REFERENCE MATERIALS FROM BAULA-NUASAHU COMPLEX, ORISSA, INDIA**

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### **ABSTRACT**

Certified reference materials (CRMs) are important for acquisition of consistent/comparable data and for reliable method validation. Any mineral exploration study involves acquiring precise dataset of the element(s) of interest in order to understand and decipher mineralization modes (Satyanarayanan et al., 2008). Studies on the platinum group elements (PGE) mineralization have been initiated currently in many regions of the country, out of which the Baula-Nuasahi Complex in Orissa has created interest among several organizations due to occurrence of relatively high modal concentrations of platinum group minerals (PGMs) (Balaram, 2006). In order to acquire accurate/precise whole rock PGE data sets, the analytical protocol mandates use of matrix matching CRMs for PGE analysis by inductively coupled plasma-mass spectrometry (ICP-MS) in combination with several separation and preconcentration techniques such as Ni-sulfide fire assay, High Pressure Asher and in combination with various chromatographic techniques (Balaram, 2008). Currently there are only few PGE CRMs available in global market and there is no PGE reference material from India that would suite the matrix of PGE mineralized rock types of our country. In order to fill this gap, two PGE reference materials representing low grade (PGE < 0.5 ppm) and high grade (PGE > 1.0 ppm) were proposed to be prepared from mafic/ultramafic rocks of Baula-Nuasahi Complex.

The Baula-Nuasahi Complex in southern part of Singhbhum Archaean nucleus in eastern India exposes series of mafic/ultramafic suites from which the Bangur gabbro (~3.1 Ga) body in the southern part of the complex is significant for PGE mineralisation. Two types of PGE mineralisation has been identified – Type 1 is a contact type “magmatic” mineralization which occurs between Bangur intrusion and its ultramafic host, and Type 2 is restricted within the breccia matrix (within the gabbro body) associated with intense “hydrothermal” alteration (Auge and Lerouge, 2004; Mondal, 2009). Bulk samples (~ 300 Kg) were collected from an underground chromite mine representing both types of mineralization for preparing two CRMs representing magmatic and hydrothermal mode of PGE mineralization. Since Type 2 was produced by late-magmatic hydrothermal remobilisation of Type 1 PGE mineralization, the former is considered to contain significantly higher concentration total PGE (high grade) than the latter (low grade). As part of the preparation of these two reference materials, an attempt is made here to study the issues related to homogenization of bulk samples that would lead to better characterization of the material, the details of which are presented in this paper.

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## GEOCHEMISTRY AND ORIGIN OF THE ARCHEAN ANORTHOSITES FROM KHAMMAM REGION, ANDHRA PRADESH

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## ABSTRACT

Anorthosites are coarse-grained cumulate igneous monomineralic rocks dominated by plagioclase megacrysts of highly calcic composition ( $An_{70-90}$ ), occurring commonly in all Archean cratons, in one or more of the three distinct associations as cumulate crystal segregations of anorthite or as megacrysts in basaltic dikes, sills, and as flows in greenstone belts that vary in metamorphic grade from greenschist to granulite facies. Anorthosites consisting predominantly of plagioclase feldspar have figured prominently in at least two distinct intervals of Earth history: the late-Archean and mid-Proterozoic. Archean anorthosites are characterized by a distinctive texture and composition, consisting of coarse equidimensional, euhedral to subhedral, calcic plagioclase megacrysts (up to 30 cm) set in a finer grained mafic matrix, and are thus distinctly different from Proterozoic massif-type anorthosites, which

occur in sialic orogenic belts, and which have lathy to platy plagioclase of much more sodic composition. The calcic composition of plagioclase thus distinguish the Archean anorthosites from their Proterozoic “massif” counterparts, which contain sodic to intermediate plagioclase in the andesine-labradorite ( $\sim\text{An}_{35-60}$ ) range. The origin of anorthosite is a multi-faceted and multi-disciplinary problem.

There are reported occurrences of archean anorthosite from different parts of Khammam schist belt (KSB) like Jannaram and Tallada. Another occurrence of small anorthosite body was reported in an arcuate shape, near Sripuram  $\sim 20$  km south west of Wyra in Khammam district. Several workers have discussed the significance of calcic anorthosite complexes for the evolution of Archean crust. But so far very little work has been carried out on Sripuram anorthosite to understand their geochemistry, origin and any mineralization they may host. In the present work a combined petrological and geochemical study has been carried out on these anorthosites.

It may be stated that Sripuram anorthosites typically shows (1) equant plagioclase megacrysts (2) highly calcic compositions (9.03% to 12.53%) and low  $\text{Na}_2\text{O}$  (0.66% to 2.76%) (3) amphibole as the dominant mafic mineral; (4) the presence of chromite, locally in ore-grade layers (5) low levels of Sr, Rb and Ba ( Sr $\sim$ 182.59ppm, Rb  $> 1$ ppm and Ba $\sim$ 80.64 ppm) (6) Ga/Al values typical of basaltic plagioclase and (8) moderately fractionated REE patterns  $\{(\sim\text{Ce}/\text{Yb})_{\text{N}} 4.99\}$ . It can be stated that mixing of igneous plagioclase of variable An-content with a mafic component having variable Mg/Fe, and containing hornblende might have given rise to these anorthosites. The petrological and geochemical characteristics suggest a primitive character for these anorthosites in similarity with Archean anorthosites world over and distinctly distinguish them from the Proterozoic massif-type anorthosites. It appears that, the only property Archean anorthosites and Proterozoic anorthosites share, is their plagioclase-rich nature, suggesting that there must be more than one process (and probably multiple processes) and different mixing models contributed in producing these anorthosites.

## **PETROGENESIS OF MAFIC FLOWS AND DYKES OF REWA, EASTERN DECCAN VOLCANIC PROVINCE: EVIDENCE FROM PGE AND RADIOGENIC ISOTOPIC ABUNDANCES**

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### **ABSTRACT**

The distribution of Platinum Group of Elements (PGE) and radiogenic isotopic abundances of Sr and Nd have been studied for a suite of flows and mafic dykes of the Rewa region in the Eastern Deccan Volcanic Province.

### **Geochemical affinity of PGE**

The prominent siderophilic and chalcophilic tendencies of the PGE are widely recognized. Siderophilic characteristics of PGE are exemplified by high concentrations (ppm levels) in iron

meteorites, the high proportion of PGE carried by iron-nickel metal in chondrites, and the strong partition of PGE in the metal phase in sulfide-bearing iron meteorites. Chalcophile characteristics are manifest in the common occurrence of high (ppm-level) PGE concentrations in association with Ni - Cu sulfide in mafic and ultramafic rocks and the occurrence of many sulfide minerals of the PGE. It is in silicate systems that the geochemical affinities of the PGE are poorly understood. Such systems are important, however, in modeling PGE ore formation.

High PGE contents are commonly associated with chromite and there is a progressive decrease in average PGE content of sulfur-poor silicate rocks from ultrabasic, through basic to intermediate-acid compositions (Crocket, 1979). These trends do not necessarily hold if silicate magma becomes saturated with respect to sulfur. PGE data on basic rocks are restricted largely to Pd and Ir. Fractional crystallization of basic magma leads to concentration of Ir, Ru and Os in early crystallizing fractions.

In a suite of twenty two samples from the Rewa region, levels of Pt, Pd, Rh, and Au were above the detection limits. Palladium values range from 2.35 to 31.8 ppb, Pt values range from 1.95 to 37.3 ppb, and Rh values range from 0.11 to 1.73 ppb. The Au values of the samples range from 1.11 to 27.7 ppb.

Keays and Lightfoot (2009) concluded that sulphur saturation is an essential requirement for PGE ore formation. Some formations of the Deccan Province from the western part indicate evidence of significant crustal contamination. Despite this, the most crustally contaminated Bushe and Poladpur lavas do not contain critical S saturation and hence the potential for ore formation is considered unsuitable (cf. Keays and Lightfoot, 2009).

### **Radiogenic isotope abundance:**

In the Deccan basalts, the initial  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios of the tholeiites at Mahabaleswar vary from 0.70391 to 0.71972. Significantly a large number of analysed tholeiites have initial  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios between 0.7040 and 0.7080.

There is no clear-cut distinction in the  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios in the different formations of Rewa from Mandla (basal) through Dhuma Fm, Pipardahi Fm to the uppermost Linga Formation except that the uppermost Linga samples have radiogenic Sr. The measured  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios of the mafic dykes range from 0.704667 to 0.71447. Assuming the emplacement age of 65 Ma,  $(^{87}\text{Sr}/^{86}\text{Sr})_i$  values vary from 0.704625 to 0.714403. Measured  $^{143}\text{Nd}/^{144}\text{Nd}$  in all the samples vary from 0.511677 to 0.512871. The samples can be grouped in two groups: one having a nearly constant Nd isotopic abundance but variable Sr isotopic composition, and the other having nearly constant  $^{87}\text{Sr}/^{86}\text{Sr}$  at 0.706 but lower  $^{143}\text{Nd}/^{144}\text{Nd}$  values.

We explain the observed variable isotopic composition of Sr and ND of the Rewa dyke samples by binary mixing between an Ambenali-type magma and a lithospheric end member with enriched  $^{87}\text{Sr}/^{86}\text{Sr}$  (~0.716) but almost constant  $^{143}\text{Nd}/^{144}\text{Nd}$  around 0.5127.

# **PLATINUM GROUP ELEMENTS AND OTHER TOXIC ELEMENTS DISTRIBUTION AND CONCENTRATIONS IN THE ENVIRONMENT WITH AN EMPHASIS ON RESPIRABLE SUSPENDED PARTICULATE MATTER (RSPM) DATA OF THE HYDERABAD CITY AND ADJOINING INDUSTRIAL AREAS**

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## **ABSTRACT**

Concentrations of the platinum group elements (PGE) especially platinum (Pt), palladium (Pd) and rhodium (Rh) in the environment have been on the rise, largely due to the use of automobile catalytic converters which employ these metals as exhaust catalysts. So far it has generally been assumed that the health risks associated with environmental exposures to PGE are minimal. More recent studies on PGE toxicity, environmental bioavailability and concentrations in biologically relevant media indicate however that environmental exposures to these metals may indeed pose a health risk, especially at a chronic, subclinical level (Kamala and Balaram, in press).

The analysis of Pt, Pd and Rh in urban airborne particulate matter is challenging, since these new pollutants are expected to increase in the environment in proportion to the increase in the number of cars fitted with catalytic converters (Ramavathi et al., 2010). These elements partially leave the surface of the catalyst during its life as a result of poorly known processes, including thermal and mechanical abrasion of the catalyst and are spreading and bioaccumulating in the environment. Platinum has been the most widely studied PGE, because it was the main active component on the early catalysts. Relevant factors in the toxicity of Pt compounds are; their physiochemical properties; dose and route of administration; and, although it is highly variable, the relationship between exposures and content in blood, serum or urine. Health symptoms such as respiratory sensitivity, the concentration in bodily fluids and other health problems increase as exposure increases (Lindell, 1997).

In this paper an attempt has been made to provide data on the environmental distribution patterns of PGE and other toxic elements in the environmental samples with a special emphasis on the RSPM samples in the Hyderabad city. The sites selected were either residential (with low traffic density), industrial or sensitive (high traffic intensity). The toxicity status of certain sites due to industrial pollution was earlier reported by Chandra Sekhar et al., (2003; 2006). A methodology using cation exchange resin is also developed for the interference free estimation of PGE by ICP-MS in selected environmental samples of Hyderabad city.

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## **DISTRIBUTION OF TRACE ELEMENTS IN PLANTS AND SOILS FROM CHROMITE MINERALIZATION OF BYRAPUR, HASSAN DISTRICT, KARNATAKA, SOUTH INDIA**

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### **ABSTRACT**

Generally many of the plants which grow in mineralized areas are known to accumulate metals, relatively in excess proportion than in non-mineralized areas. Plants that hyper accumulate metals have great potential for application in remediation of metals in the environment. This approach is emerging as an innovative tool with greater potential for achieving sustainable development and also to decontaminate metal polluted air, soil, water and for other environmental restoration applications. Metal hyperaccumulating plants are useful in phytoremediation, and play a vital role in biogeochemical prospecting, and have implications on human health through food chain. The composition of plant tissues reflect the composition of the soil in which the plant grows. This interrelationship however, is modified in many plants by tolerance mechanisms. Thus plants are able to accumulate most chemical elements, and many species are sensitive indicators of the chemical environment in which they grow, and also the elemental content in individual plants of the same species may be divergent..

The present study focuses on the metal concentration in different plant species and their substratum in the Byrapur chromite mining area of Hassan District, Karnataka which comes under Nuggihalli Schist belt. Plant organs of different species and their corresponding substrate samples were collected. Root, stem, and leaves of *Chromolaena odorata*, *Sopubia delphiniifolia*, *Tephroisa purpurea*, *Pavetta indica*, *Prosopis juliflora* and their soil samples were analyzed for mineral elements viz., Ba, Sr, Mn, B, Cu, Zn, Pb, Ni, Co, Cr, Mo, Cd, Sn, Zr, and As; and the biological absorption co-efficient (BAC) was calculated. The results show the presence and/or absence of certain elements in plants and soils, which can be explained on the basis of biogeochemical cycling of elements, exclusion mechanisms, and bioavailability. The roots of *P. indica* show the unusually high concentration of 413 ppm of Zn. Similarly, the leaves of *T. purpurea* show unusually high concentration of 75 ppm of Co and these plant species may be considered as accumulator plants. The biological absorption coefficient (BAC) is used to characterize the absorption of chemical elements by plants from their substrate. The BAC is the ratio of the concentration of an element in plant ash to that of its substrate. The BAC values for the roots of *P.indica* for Pb (BAC 7.66) and leafs of *C. odorata* for B (BAC 2.68) are found to be significantly high. Based on the biological absorption coefficient (BAC) *P.indica* for Pb and *C. odorata* for B may be

considered as accumulator plants. Such plant species may be useful in reclamation and revegetation of adversely affected mining environments; and further these investigations are also useful in biogeochemical orientation surveys. Further, this study has given greater scope on the plant-soil relationship in the mining area and their significance in environmental studies.

## **GEOCHEMICAL STUDIES ON THE LATE ARCHEAN BLACK SHALES OF CHITRADURGA SCHIST BELT, DHARWAR CRATON, INDIA: IMPLICATIONS FOR THE PROVENANCE AND METALLOGENY**

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### **ABSTRACT**

Chitradurga Schist Belt (CSB) which extends in a NS direction for about 450 km, is one of the well-known Late Archean tectonic sections and black shales in association with quartzite, comprises greywacke-phyllite, conglomerate, metavolcanic, banded iron formation and chert. Until recently majority of the work carried out on these Late Archean volcanosedimentary sequences in CSB has been focused on the geological, geochemical and tectonic evolution of chemogenic BIF's, chert and clastic rocks of greywacke-phyllite. However, the black shale associated with metavolcanic and meta sedimentary rocks of CSB have received less attention in recent years. The black shales also are found to host gold and base metal mineralization. In view of their geological, geochemical and economic importance, an attempt is made in the present work to understand their genesis and environments of deposition of these shales. Mineralogically quartz and clinocllore dominate these clastic sediments and minor phases include muscovite, albite and microcline along with carbonates such as calcite and dolomite. Opaques are represented by goethite, marcasite and sulfides mostly by pyrite and  $\pm$  arsenopyrite. Presence of marcasite indicates the shallow marine environment and their deposition under reducing conditions. The black shales from CSB have Chemical Index of Alteration (CIA) values ranging from 60 to 80 and average Chemical Index of Weathering (CIW) of 77, which suggest intense chemical weathering of the source. REE patterns are identical to those of the basaltic source. The chondrite-normalized REE patterns of these clay-rich sediments show LREE depletion and positive to negative Eu anomalies and flat to enriched heavy REE. High  $La_N/Yb_N$  ratios averaging 4.9, and  $Gd_N/Yb_N$  ratios lower than 2.0 are observed in these sediments indicating that these sediments have fractionated LREE patterns (average  $Ce_N/Sm_N = 2.04$ ) with feeble negative Eu anomalies (average  $Eu/Eu^* = 0.88$ ) and flat HREEs (average  $Gd_N/Yb_N = 1.13$ ). The Th, La, Sc and Sc, Th, Zr/10 concentrations suggest their derivation from Active Continental Margin (ACM) / island arc setting. These Shales are enriched in the  $TiO_2$ , MgO and FeO concentrations as compared to UCC which indicate their derivation from high mafic source with minor felsic rocks which acted as provenance for these unusual late Archean metasediments in Dharwar Craton.

**GEOCHEMISTRY OF ENERGY  
RESOURCES:  
ATOMIC MINERALS**

# URANIUM EXPLORATION IN INDIA, PRESENT STATUS & FUTURE STRATEGIES

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## ABSTRACT

Exploration for Uranium in India dates back to 1949, where surveys to locate atomic minerals were initiated in the well established Copper Thrust Belt (CTB) of Singhbhum, in the present day Jharkhand state. Based on the limited understanding on uranium geology, the thrust zones of Singhbhum which were popularly known for hosting Copper mineralization were targeted presuming sympathetic relation between Copper and Uranium. Subsequent exploration in different phases in the Singhbhum Shear Zone (SSZ), resulted in identifying a number of uranium deposits all along the shear zone from Bagjata-Kanyaluka in the Southeast to Lotapahar in the northwest. As the geological and geochemical understanding of uranium mineralizing events was evolved with time, concept based exploratory efforts in potential geological domains resulted in identifying a number of potential and promising uranium provinces in the country. The potential uranium provinces include the Singhbhum Shear Zone (SSZ), Dharwar Craton, the Lesser Himalayan Belt, Dongargarhs, Aravallis, Siwalik belt and the Mahadek basin. Initial efforts in uranium exploration were to look for uranium mineralization hosted in Quartz Pebble Conglomerate (QPC) of the Palaeo Proterozoic Basins, Sandstone type in the Phanerozoic Basins, and hydrothermal vein type mostly in the basement rocks of the shield areas. These surveys paid rich dividend in the form of identifying QPC type mineralization in the Dharwars in Southern India, Dhanjoris in Eastern India and the base of Iron ore Group in the Central Indian Craton, classical hydrothermal vein type of mineralization in Singhbhum Shear Zone, Parts of Central Indian Craton, Lesser Himalayas, southern parts of Cuddapah Basin, apart from Sandstone hosted mineralization in the Mahadeks, Gondwanas and Siwaliks .

Discovery of large tonnage-high grade Lower-Middle Proterozoic unconformity deposits in parts of Canada and Australia, brought in a paradigm shift in the exploration strategy in India. With the objective of identifying similar deposits, the Proterozoic basins of India viz., Cuddappah , North Delhi Fold Belt, Bhima, Kaladgi-Badami, Chattisgarh, Indravati, Bijawar and Vindhyan Basins were targeted for locating high grade, large tonnage unconformity type uranium deposits, due to their geological favourability in hosting such type of uranium mineralization. Our concerted efforts yielded results when in 1991, unconformity associated uranium mineralisation was first discovered in Lambapur-Peddagattu-Chitrial areas in the Srisailam-Palnad Subbasins of the Cuddapah Basin. Subsequent detailed exploration in the Srisailam- Palnad sub basins has resulted in establishing economically viable uranium deposits in Lambapur-Peddagattu and Chitrial areas, which contributes substantially to our existing uranium resources. Encouraged by the discovery in the Cuddapah Basin, AMD intensified surveys targeting other potential Proterozoic Basins, which resulted in establishing significant uranium mineralization in Gogi in the Bhima Basin and Deshnur in the Kaladgi Basin, which are currently under active exploration. Vempalle Dolostone hosted Uranium mineralization in Tummalapalle-Rachakuntapalle in Kadapa district; Andhra Pradesh is a unique deposit of its kind, which is the major contributor to the uranium resource base of the country. This stratabound uranium mineralization

extending from Reddipalle in the north to Maddimadugu in the south all along the western parts of Cuddappah Basin has a huge potential, which is currently being explored by AMD. India has potential to host Iron Oxide Breccia (IOB) type uranium deposits. The Dhala Structure with a present day apparent diameter of 11 km, located in the northwestern part of the Archean Bunelkhand Craton, which appears to be the eroded remnant of an impact structure, is explored for hosting IOB type uranium mineralization.

The importance of Geophysical surveys, both airborne and ground geophysics in identifying these type of deposits has since been realized, AMD has embarked upon massive Time Domain Electromagnetic surveys (TDEM) to explore favourable geological territories. Having covered all accessible areas with surface outcrops by radiometric surveys, it has become necessary to explore the deeper parts by indirect exploration tools viz. geochemical and geophysical techniques. AMD is currently engaged in integrated surveys with due inputs from geological, geophysical and geochemical domains to identify newer areas and bring them under the purview of detailed exploration. With the state of the art hydrostatic drilling rigs it is planned to explore prospective Proterozoic Basins extensively for the next 10 years period to assess their geological potential to host high grade/ large tonnage uranium deposits. Exploration for uranium over the past six decades has resulted in identifying eleven major uranium deposits distributed in varied geological environs all over the country. Apart from conventional uranium mineralization, non-conventional resources like phosphorite, black shale etc. have immense potential. Even though their uranium grades will be of lower order, their uranium content will be huge due to their extensive size. In addition to intensifying uranium exploration in potential geological domains, AMD also plans to tap the non-conventional resources which will add substantially to the resource base.

## **RARE METAL AND RARE EARTH MINERALIZATION IN DIFFERENT GEOLOGICAL ENVIRONS OF INDIA**

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### **ABSTRACT**

Rapid industrialization and urbanization worldwide has necessitated search for new materials and technology that are helpful to man and at the same time that are environment friendly. Advances in science and modern technology in twentieth century, especially in the fields of space, nuclear energy, electronics, computers, telecommunications, information technology, superconducting materials, permanent magnets, rechargeable hydride batteries and super alloy steels have brought a host of rare metal and rare earth elements to lime light. The Rare Metals (RM) include lithium, beryllium, zirconium, niobium, tantalum, uranium and thorium. Rare Earths (RE) are coherent group of elements from La (Z=57) to Lu (Z=71) along with Y (Z=39) and Sc (Z=21) having similar chemical and physical properties. Some of these metals have gained strategic status due to politico-economic reasons. Their strategic nature and gradual depletion of high grade resources have led to sustained efforts to harness lower grade resources.

RM and RE are more widespread in the earth's crust than the elements commonly known in our daily life. More than 200 minerals of RM and RE are distributed in a wide variety of mineral classes.

They occur as oxides, carbonates, phosphates, halides and silicates. Sources of RM and RE include granite pegmatites, volcanic tuffs, granites, alkaline-ultramafic and carbonatite complexes, wide variety of placers, Fe-carbonate rocks and brines. Major economic deposits are mainly confined to pegmatites, granites, carbonatites and their placers in Precambrian and Phanerozoic terrains. Prominent resources have been identified in China, Brazil, Canada, Nigeria, Western Australia, Zaire, USA, USSR, Argentina and South Africa. In India RM and RE are associated with pegmatite belts in Bihar, Rajasthan, Andhra Pradesh, Karnataka, and Chhattisgarh; younger granites of Andhra Pradesh and Gujarat; carbonatites of Tamil Nadu, Meghalaya and Assam and beach placers of east and west coasts.

Granite pegmatites constitute well defined pegmatite belts, groups and clusters in Precambrian metasedimentary and metabasic terrains in different parts of the Indian Shield. The major pegmatite belts of Bihar, Rajasthan and Nellore in Andhra Pradesh are associated with commercial mica and subordinate rare metal mineralization. Among the pegmatites, the rare element class of pegmatites, contain extensive and diversified mineralization of RM and RE. The pegmatites of this class are genetically divided into three petrogenetic families of LCT, NYF and mixed types. Typical RM and RE pegmatites with Li, Be, Nb, Ta, Sn, Y, Th, U and REE minerals without commercial mica occur in Bastar-Malkangiri Pegmatite Belt (BMPB) in Chhattisgarh and Orissa, Holenarsipur and Nagamangala schist belts of southern Karnataka and pegmatites of Jharsuguda district in northern Orissa. Lepidolite, amblygonite, spodumene, beryl, columbite-tantalite, ixiolite, samarskite and monazite are the major RM and RE minerals in these pegmatites. The pegmatites of BMPB and Karnataka with Li, Be, Ta > Nb and Sn mineralization belong to LCT family and those of northern Orissa with Be, Nb > Ta, Y and REE mineralization belong to NYF family.

The major types of granite-related RM and RE deposits include those in which rare metal minerals form as an integral part of the crystallization history, generally within the more evolved facies of the granite and those in which pervasive hydrothermal alteration accompanied mineralization. Peralkaline to peraluminous A-type granites of Kanigiri, in the alkaline complex of Prakasam district, Andhra Pradesh along the eastern margin of Cuddapah basin have been found to be enriched in Nb, Ta, Sn, U, F, Th and Rb. Discrete columbite, samarskite and monazite occur in this granite along with ilmenite, magnetite, zircon, garnet, rutile etc. The age of the granites has been estimated to be  $995 \pm 20$  Ma by Rb-Sr data of biotite. The younger granites of Idar and Umedpur in Gujarat also contain appreciable concentration of rare metals - Nb (71-226ppm), Y (72-166ppm) and the soils from these granites contain upto 12.79% Nb<sub>2</sub>O<sub>5</sub> and 3.17% Ta<sub>2</sub>O<sub>5</sub> with discrete minerals of columbite-tantalite, xenotime, zircon, rutile and sphene.

In India, most of the carbonatites occur either in Precambrian Shield areas or are associated with Deccan Trap activity of Tertiary age. Carbonatites are known from Ambadongar, Newania, Sevathur, Samalpatti, Sung valley and Samchampi. Carbonatites of Sung valley in Meghalaya, Sevathur in Tamil Nadu and Samchampi in Assam are associated with appreciable quantities of Nb and REE with pyrochlore, fergusonite, xenotime, allanite and zircon.

The beach sand placers occurring along the eastern and western seaboard of India constitute an important source of REE (monazite) along with other heavy minerals like ilmenite, rutile, zircon, garnet and sillimanite. Inland placers located in parts of Chhotanagpur granite plateau in Ranchi district, Jharkhand and Purulia district, West Bengal are also found to contain rich concentration of heavy minerals including monazite. Riverine placers in Jashpur and Surguja districts in Chhattisgarh and Gumla and Garhwa districts in Jharkhand contain appreciable Y and REE with xenotime and monazite.

# PERALUMINOUS GRANITES: POTENTIAL SOURCE FOR URANIUM MINERALIZATION IN KOPPUNURU AREA, GUNTUR DISTRICT ANDHRA PRADESH.

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## ABSTRACT

Atomic Minerals Directorate has established uranium mineralization in Koppunuru area lying to the western part of Palnad Sub basin. The granitic rocks with high intrinsic uranium content (27.88 ppm, N=968) forms the basement for Banganapalli and Narji Formations of Kurnool Group. Basement granites are potash rich, low calcic and peraluminous in nature. Geochemically, the granites (N=19) are characterized by high  $Al_2O_3$  (13.31-24.23%), and moderate  $SiO_2$  (62.09-74.01%) & FeO (1.41-4.11%), Low MgO (0.03-1.63%) & CaO (0.11-1.84%) and very low MnO (0.01-0.04%) content. They are mainly low sodic with  $Na_2O/K_2O$  ratio varying from 0.09- 0.95 (Av.0.63, N=14). A few samples show high sodic nature with  $Na_2O/K_2O$  ratio varying from 1.00- 1.68 (Av.1.26, N= 5). Compositionally, they are granitic to granodioritic in nature and are peraluminous with A/CNK ratio >1.1. Granites are mainly A-Type and characterized by high U/Th ratio (0.05-24.50, Av.= 4.41). Uranium content varies from <5 to 59 ppm with an average 32 ppm (n=16) (excluding the mineralized samples) whereas thorium content varies from <5 to 140ppm in the study area.

Petrographically, these granites are essentially composed of quartz, orthoclase, microcline, perthite, and plagioclase. Biotite and zircon are present as accessory minerals. Besides minor ore minerals like pyrite, chalcopyrite, galena, goethite and leucoxene are also observed. Mineral alterations are characterized by assemblage of sericite, muscovite and chlorite. Biotite is often squeezed along the intergranular spaces, highly bleached and altered to muscovite. Primary uranium minerals pitchblende and coffinite are found to occur as stringers and veins. Besides variable concentrations of uranium are associated with biotite and hydrated iron oxide along the basement fractures. These favorability features and high intrinsic content of uranium in the basement granite make it a potential source for uranium mineralization in the overlying Kurnool sediments in Koppunuru area.

# LITHOSTRATIGRAPHIC AND RADIOMETRIC APPRAISAL OF SRISAILAM AND PALNAD SEDIMENTS IN KOTTAPULLAREDDIPURAM–ACHCHAMMAGUNTA–RACHCHAMALLEPADU AREA, GUNTUR DISTRICT, ANDHRA PRADESH: A STRATIGRAPHIC DRILLING APPROACH

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## ABSTRACT

In the northern part of Cuddapah basin, Meso- to Neoproterozoic sediments are deposited in two sub-basins i.e., Srisailam and Palnad, over Neoarchean to Palaeoproterozoic basement granite and gneisses with younger felsic and mafic intrusives. The Srisailam sub-basin exposes predominantly low dipping ( $2^{\circ}$ - $11^{\circ}$ ) arenaceous sequence whereas the Palnad sub-basin is represented by arenaceous–argillaceous–calcareous cycle. These lithounits are affected by a number of lineaments, faults and fractures signifying reactivation in the area. Marginal parts of these sub-basins have indicated significant unconformity proximal uranium mineralisation at Lambapur–Peddagattu–Chitrial (dominantly granite hosted) and Koppunuru–Dwarkapuri–Chencu Colony (dominantly sediment hosted) areas. Similarly, granite hosted lean uranium mineralisation is also reported from Rallavagu Tanda–Sajjapur–Virilapalem area in the northeastern part of the Palnad sub-basin. The marginal parts of Srisailam and Palnad sub-basins exhibit low thickness (upto 139m) of sediment cover as compared to the classical unconformity type uranium deposits reported elsewhere in the world. In view of this, the deeper parts of these sub-basins were subjected to stratigraphic core drilling to ascertain unconformity depth, lithostratigraphic and lithostructural details and to assess the potentiality of uranium mineralisation.

Kottapullareddipuram and Achchammagunta sector exposes sub-horizontal beds of Srisailam quartzites showing easterly dips close to faulted contact with Palnad sediments whereas westerly and southwesterly gentle dips are observed in other parts. Sub-surface borehole lithologs have indicated a thick succession of quartzite with shale–siltstone intercalations in the deeper part of the sub-basins. The unconformity depth varies from 344.80m to 419.40m in Kottapullareddipuram and 254.35m to 394.45m in Achchammagunta sectors. It is also apparent to note that the sediment thickness increases due south and southeast of the Srisailam basin in this part. Srisailam Formation is predominantly represented by grey to brownish grey quartzites and shale-siltstone intercalations, followed by purple siltstone–grey to greenish shale intercalations. These sediments are deposited over basement granitoids with mafic intrusives. Both, granitoids and sediments, are affected by significant fracturing with the dominance of WNW–ESE and NNE–SSW fractures. Besides, syndimentary deformation is also common in Srisailam sediments. Infiltration of iron oxide solution through weaker plains is quite apparent.

Rachchamallepadu area, which is located in the southerly upthrown block of Kandlagunta fault in Palnad sub-basin, exposes thick sequence (117.15m to 173.25m) of Palnad sediments (Narji and Banganapalle Formations), which are underlain by 113.85m to 181.05m thick sequence of quartzite and siltstone-shale intercalations belonging to Srisailam Formation. These are deposited over basement granitoids. Three boreholes have intercepted unconformity at 231m, 354.30m and 348.60m along E–



W section line. Thinning of sedimentary column in the area E of Rachchamallepadu is probably due to the presence of NNE–SSW trending fault. This is further substantiated by the presence of brecciation, ferrugination and silicification with minor slippages/displacement of beds as evidenced in borehole cores. Palnad sediments are predominantly represented by Banganapalle Formation, however, Narji limestone capping is observed in one borehole. Banganapalle sediments are constituted of quartzites, shale–siltstone intercalations and quartzite–shale intercalations with gritty quartzite at basal part. However it is conspicuous to note that basal gritty horizon is missing in eastern section.

Radiometric examination has indicated presence of lean mineralisation ranging from 0.010%  $eU_3O_8$  x 0.20m to 1.70m and 0.016%  $eU_3O_8$  x 0.70m in granitoid in different borehole sections while shale hosted lean mineralisation (0.023%  $eU_3O_8$  x 1.10m) is recorded only in one borehole section in Rachchamallepadu area. The lean uranium mineralisation is probably due to the absence of basal gritty horizons (Banganapalle Formation) and less fractured and altered nature of basement granitoids as compared to Koppunuru area.

## **GEOLOGICAL AND GEOCHEMICAL STUDIES ALONG ZONE OF ALBITISATION FROM ROHIL TO RAMBAS IN KHETRI SUB BASIN OF NORTH DELHI FOLD BELT, INDIA**

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### **ABSTRACT**

Delhi Supergroup rocks of Mesoproterozoic age extend over 700 km in strike from Delhi in the north to Palanpur in the south and unconformably rest over Archaean basement (BGC) and show evidence of poly phase deformation and varied degree of metamorphism. These volcano-sedimentary rocks are further divided into North Delhi Fold Belt (NDFB) and South Delhi Fold Belt (SDFB). The NDFB extends from Delhi to Ajmer and comprises three sub basins. Of these, the western most basin, i.e. Khetri sub basin is characterized by NNE-SSW trending prominent zone of albitisation over 170 km strike length and 6-10 km in width. Rocks are moderately to intensely altered along this zone and recorded numerous radioactivity anomalies in both albitised and non-albitised metasediments. Subsurface exploration in Rohil area has proved about 5000 tonnes of uranium deposit of 0.06%  $U_3O_8$  over a strike length of 700 m at the sheared contact of quartzite and quartz biotite schist. Uraninite with minor brannerite and coffinite are the main uranium minerals. Felsic components have been identified in metasediments from Udaipurwati, Dhanota area, which is corroborated by high barium content. Agpaitic coefficient of these rocks indicates positive correlation with uranium. In Rohil area, light REE and heavy REE show flat trend with prominent negative Eu anomaly.

Rocks have undergone regional metasomatic alterations as evidenced by the presence of high soda and depleted potassium. Signature of Ca metasomatism has also been recorded in addition to Na metasomatism in calc silicate rocks.  $Al_2O_3$ , Zr, Nb, Y remained immobile during metasomatism of the rocks that proceeded from an initial stage of chloritisation and albitisation mainly by addition of  $MgO$ ,

FeO, and Na<sub>2</sub>O. Though uranium mineralization mostly occurs with albitite zone, there is no direct correlation of soda content and uranium mineralization. In Raghunathgarh, uranium mineralization occurs in sheared quartzite with no signature of albitisation.

Uranium mineralization is post metasomatism and occurs within shear zones. Mineralisation is associated with wall rock alteration, due to ore fluid interactions which were generated during thermal imprint of post orogenic magmatism (850 Ma) and caused mobility of uranium along with sulphide mineralization. It is observed that intense pervasive hydrothermal alterations are well developed in Rohil and nearby areas where intense fracturing and shearing has permitted mineralizing fluids to pass and form ore. In Rambas-Gorir-Dhancholi areas, calc silicates rocks predominate and intensity of shearing and fracturing is lesser compared to Rohil area. Post metasomatic quartzofelspathic veins/pegmatoids intruded in to Delhi metasediments are thoriferous with low uranium content, which is distinct from uranium mineralized zones within Delhi metasediments.

## **MINERALOGICAL CHARACTERIZATION OF MINE SAMPLE OF GOGI URANIUM DEPOSIT, KARNATAKA, INDIA**

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### **ABSTRACT**

The ultimate aim of mineral processing operation is effective separation of the valuable ore from the gangue with minimum loss. A thorough understanding of mineralogical characteristics of the ore deposit is essential to develop and employ a maintainable, efficient and relatively less expensive recovery. The processing and extraction route for uranium ore is largely influenced by the nature and amount of constituent minerals, their associations, intergrowths, grain size, etc. This study was intended to characterize the mine sample and provide relevant background information on mineralogical composition, nature of radioactive minerals, associated sulphides and liberation characteristics of uranium minerals by which the processing of the ore could be effectively achieved.

The Gogi uranium deposit occurs in the southern margin of the Bhima Basin in Karnataka. Mineralization is hosted by both basement granites and overlying Shahabad limestones. An integrated approach consisting petrography, sizing, density fractionation of the sized ore followed by quantitative mineralogical estimation by conventional microscopic grain counting of the polished grain mounts has been carried out for the estimation of constituent minerals and liberation of uranium values in the sample.

The mineralogical composition of the sample indicates radioactive ore minerals (0.886%), non radioactive ore minerals (6.58%) and gangue minerals (92.539%). The radioactive ore minerals are coffinite, the predominant uranium phase, followed by pitchblende, urano-organic complex and some labile uranium that occurs in association with hydrous iron oxides, clay segregations with carbonate mud. Among non radioactive ore minerals sulphides are predominant over oxides. Pyrite is by far the most abundant mineral followed by chalcopyrite and galena. Oxides are represented mainly by goethite

with traces of magnetite and hematite. Calcite (61.57%) and quartz+chert (13.10%) are major gangue minerals associated with subordinate amounts of feldspar (1.59%), biotite + chlorite + clay (5.89%). Dolomite, hornblende, epidote, zircon and barite form the minor component of the gangue. Thus the gangue mineralogy corroborates major percentage of limestone component in the ore compared to granitic component.

The uranium values are high in coarser fractions. Around 60-70% of uranium values are associated with Methylene Iodide Heavies where discrete phases are predominant. Around 5% is accounted by dispersed uranium with carbonaceous matter, goethite and clay segregations in association with carbonate mud which are common in Bromo Lights. Both discrete phases and dispersed uranium are noticed in Methylene Iodide Lights that contribute to around 30% of uranium values.

Thus the mineralogical characterization of the ore suggests an alkali leaching route to process the ore as the gangue mineralogy contains major limestone component and optimal crushing of +100# for liberation of uranium as coarser fractions contain more uranium.

## **PRELIMINARY STUDIES ON GEOCHRONOLOGY AND GEOCHEMISTRY OF URANIFEROUS GRANITES FROM CHITRIAL AREA, NALGONDA DISTRICT, ANDHRA PRADESH**

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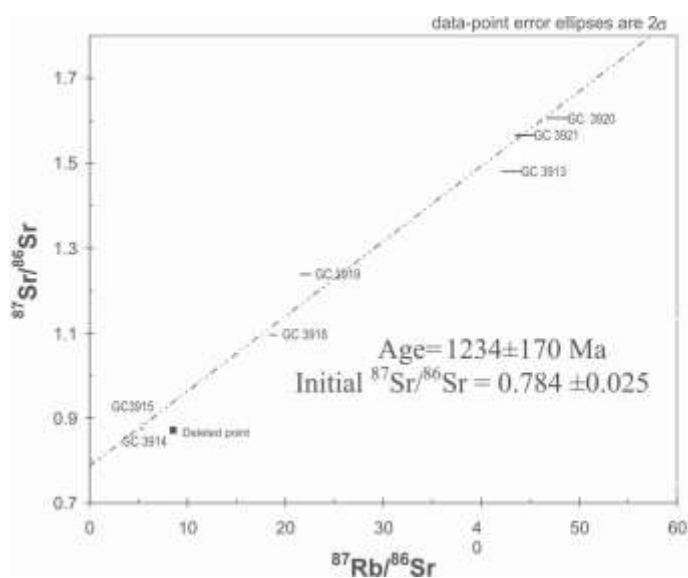
### **ABSTRACT**

The crescent-shaped Cuddapah basin, covering an area of 44,500 Sq km is the second largest among the Purana basins in Peninsular India and has been considered highly promising for exploring unconformity-related uranium mineralization. The Atomic Minerals Directorate (AMD) for Exploration and Research had initiated reconnaissance radiometric survey in the Cuddapah basin and significant radioactive anomalies due to uranium were located in the basement granitoid close to the non-conformity contact with the Middle to Upper Proterozoic cover rocks of the Srisailam Formation, around Chitrial village, Nalgonda District, Andhra Pradesh [1]. The Chitrial outlier of Srisailam Formation covering 60 Sq Kms rests unconformably over the basement granitoids. The radiometric ages of basement granitoids under the Cuddapah basin obtained from other parts range from 2.4 - 2.5 Ga.

In the present study, eight borehole core samples, both radioactive and non-radioactive, from basement granitic rocks drilled through Chitrial outlier were taken up for geochemical analysis using WDXRFS and geochronological studies using TIMS. These granites have analyzed very high SiO<sub>2</sub> (68.68-75.83 %), high K<sub>2</sub>O (4.39-9.11%), low Na<sub>2</sub>O (0.35-3.88%) with K<sub>2</sub>O > Na<sub>2</sub>O and K<sub>2</sub>O/Na<sub>2</sub>O (1.50-6.69), low CaO (0.04-0.24 %). These have also analyzed high Rb (217-376 ppm), low Sr (17-135 ppm) with Rb > Sr, Y (16-58 ppm), Ce (25-238 ppm), Zr (118-318 ppm) and Ba (376-925 ppm). Geochemically, these granites are comparable with the average Proterozoic Granites except their very low CaO (0.04-0.24 %) content. In R1-R2 plot, all the samples plot in the granite and alkali granite field. In general, the samples are low calcic, high potassic and peraluminous in nature. They vary from normal granite to differentiated granite in the Rb-Ba-Sr triangular variation diagram. These samples

are anomalous in uranium and the radioactive horizon analyzed up to 523 ppm with low Th, indicating presence of uranium phases. The average lower crust normalized plot shows enrichment of U, Rb, Ce, Zr and Y and depletion of Ba, Sr and Ti indicating their evolved nature.

For geochronological studies, conventional isotope dilution techniques were used for the estimation of Rb, Sr and the isotopic ratios were measured on a VG 354 multi-collector mass spectrometer following the procedure described elsewhere [2]. Rb and Sr abundances thus obtained range from 211 to 354 ppm and 15.9 to 136 ppm respectively and the values are in agreement with XRF data. The  $^{87}\text{Rb}/^{86}\text{Sr}$  and  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios in these samples vary from 5.40 to 47.8 and 0.87089 to 1.6024 respectively. Seven out of the analyzed eight samples, when regressed together indicate an isochron age of  $1234 \pm 170$  Ma (MSWD = 95) with initial  $^{87}\text{Sr}/^{86}\text{Sr}$  ratio of  $0.784 \pm 0.025$ . Semi-quantitative U and Th data by geochemical (XRF) studies shows that the analyzed core samples have higher U/Th ratio in the range of 0.62-5.68 compared to average value of 0.26 in granitic rocks.



It is therefore inferred that the Rb-Sr age of  $1234 \pm 170$  Ma with very high initial  $^{87}\text{Sr}/^{86}\text{Sr}$  of 0.784 is the time of the Sr isotopic re-homogenization during an episode of fluid interaction possibly related to process of U mineralization.

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# SEPARATION OF ZIRCON FROM THE BEACH SAND DEPOSIT OF SRIKURMAM AREA, SRIKAKULAM DISTRICT, ANDHRA PRADESH- A CASE STUDY

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## ABSTRACT

Beach sand placer deposits occur along the eastern and western coasts of India, which contain heavy minerals, such as ilmenite, rutile, garnet, monazite, zircon and sillimanite. Among these, zircon is used in zircoalloys (nuclear industry), ceramics, refractories, abrasives, etc. Separation and chemical characterization of pure zircon is a prelude for understanding the different elements and impurities present and its industrial application. In recent times, several methods are developed for beneficiation and separation of individual heavy minerals from beach sands.

In this paper, separation of zircon from beach sand of Srikurmam area, Andhra Pradesh was taken up as a case study. The process flow sheet adopted for separation and isolation of pure zircon from beach sand sample consists of desliming of beach sand, wet tabling of sand fraction, removal of magnetite by low intensity magnetic separation from table concentrate, perm roll magnetic separation and induced roll magnetic separation of table concentrate. The concentrates were further subjected to iso-dynamic magnetic separator after observing impurity present in the sample under binocular stereomicroscope. In the present process, about 95% pure zircon was obtained. Further concentration of zircon was carried out under the binocular stereomicroscope by hand picking of impurity to obtain 99.5% pure zircon concentrate. The pure zircon concentrate was analyzed for major, minor and trace elements by chemical method for characterization of zircon and cross validation of physical processes through which the zircon concentrate was obtained.

Chemical analysis of the pure zircon concentrate indicated 63.15 to 64.79%  $ZrO_2$  and 32.2 to 32.8%  $SiO_2$ . These values are nearer to that of pure zircon, which stoichiometrically contains 67.2%  $ZrO_2$  and 32.8 %  $SiO_2$  with little iron. In the present study,  $ZrO_2+HfO_2$  content varies from 65.27 to 66.17% and hafnium from 1.25 to 1.46%  $HfO_2$  in the zircon concentrate. The variation of  $ZrO_2$  can be accounted due to the presence of hafnium and iron. The uranium and thorium content varies from 0.040 to 0.048%  $U_3O_8$  and 0.012 to 0.042%  $ThO_2$  respectively. Other oxides are present in minor to trace amounts. The usage of zircon at industrial scale depends on the amount of  $ZrO_2+HfO_2$ ,  $Fe_2O_3$ , and  $TiO_2$  along with other oxides. The paper deals with the physical beneficiation methods adopted and correlation between chemical analysis and stoichiometric content of zircon concentrate separated from the raw sand.

# **GEOCHEMISTRY OF BASEMENT GRANITES OF KOPPUGATTU-BAMANAPALLE SECTOR IN THE NORTHERN MARGIN OF CUDDAPAH BASIN – IMPLICATIONS FOR UNCONFORMITY RELATED URANIUM MINERALISATION**

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## **ABSTRACT**

Uraniferous anomalies have been reported for the first time in Koppugattu (16°27'1"N; 78°47'46"E) – Bamanapalle (16°26'3"N; 78°47'2"E) sector of Amrabad outlier in the northern margin of Cuddapah basin, Mahboobnagar district, Andhra Pradesh, associated with the unconformity contact between the Lower Proterozoic basement and Middle-Upper Proterozoic sediments of Srisailam Formation. The area lies to the SW of Chitrial outlier and forms part of the main Srisailam sub-basin.

The basement consists of granitoids intruded by basic dykes and quartz veins. The granitoids exposed comprise coarse grained grey biotite granites with occasional pink granites. Highly chloritised granites occur around Amrabad, Rayalagandi and Madhavanpalle areas. Occasionally, enclaves of metasedimentary rocks are seen in basement which include amphibolites, gneisses showing pygmatic folding and metaquartzites that show cross beddings. The fractures and the basic dykes in the basement have a dominant N-S trend followed by NW-SE and NE-SW directions. The overlying sediments of Srisailam Formation are unmetamorphosed and mainly consist of arenaceous lithounits with minor intercalations of argillaceous rocks. Thickness of the sediments is about 60m with shallow dips of less than 10° towards southeast.

Several uraniferous anomalies recorded at Koppugattu (0.040% U<sub>3</sub>O<sub>8</sub>; 0.070% ThO<sub>2</sub>), Bamanapalli (0.50% U<sub>3</sub>O<sub>8</sub>; <0.010% ThO<sub>2</sub>), Madhavanpalle (0.053% U<sub>3</sub>O<sub>8</sub>; <0.005% ThO<sub>2</sub>), etc. indicate that uranium mineralization is mainly confined to altered basement granites close to the unconformity.

Radioelemental content of the granitoids (U= 9-21 ppm; Th= 36-46 ppm; n=7) indicate the fertile nature of the granitoids and the Th/U ratio of 0.22 to 4.0 against the crustal average value of 4. XRF analyses of the twenty six samples of the basement indicate that geochemically they are of varied nature with the samples falling in normal granites, alkali feldspar granites and granodiorite fields in Na<sub>2</sub>O+K<sub>2</sub>O vs SiO<sub>2</sub> binary variation diagram. A/CNK vs. A/NK binary variation plot of these granites shows peraluminous to meta-aluminous nature. This is also substantiated by the high Rb/Sr ratios (1.13-6.88). The average crust normalized trace element spider diagram indicates enrichment of U, K, Ce and Y and depletion of Sr, Ti and Ba. Most of the granite samples fall in the 'strongly differentiated granites' field in Rb-Ba-Sr triangular plot. The Rb vs. Sr plot indicates depth of granite formation close to lower crust. Geochemically, these granites are similar to granites of Chitrial area where significant uranium mineralisation has already been established.

Occurrence of highly uraniferous anomalies along unconformity in the Koppugattu-Bamanapalle sector and geochemical similarity of its basement characters with Chitrial area indicate that the area around Amrabad outlier in the main Srisailam sub-basin has significant potential to host unconformity related uranium mineralisation.

# GEOCHEMISTRY AND SR AND PB ISOTOPE SYSTEMATICS OF BASEMENT GRANITOIDS FROM NORTH AND WEST OF PALNAD SUB-BASIN, GUNTUR AND NALGONDA DISTRICTS, ANDHRA PRADESH

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## ABSTRACT

Palnad Sub-basin, one of the important geological domains for unconformity-related uranium mineralisation, is surrounded by basement granitoids in the northern and western parts. These granitoids exhibit medium to coarse grained, holocrystalline granular nature and hypidiomorphic, inequigranular texture. Major mineral composition is represented by microcline, orthoclase perthite, plagioclase and quartz, whereas minor and accessory minerals include hornblende, chlorite, epidote, apatite, zircon, anatase and sphene. Banganapalle sediment cover over basement granitoid has shown immense potential of fracture-controlled epigenetic type uranium mineralisation (0.13–0.55%  $U_3O_8$ ) in Koppunuru–Dwarakapuri area, Guntur district, Andhra Pradesh. It is also observed that basement granitoids in these parts have high intrinsic uranium (19 ppm; U/Th ratio 3.80; n = 30) and found to be main source of uranium in the system, which was probably released, remobilised and concentrated at suitable structural locales during the basement reactivation.

Geochemically, these granitoids (n=8) show wide variation in  $SiO_2$  (61.81–69.31%; av. 65.78%), MgO (0.54–3.14%; av. 1.64%), and CaO (0.34–5.98%; av. 3%) contents while  $Al_2O_3$  exhibit restricted abundance (14.31–17.24%; av. 16.39%). Total alkali content varies from 7.71 to 9.22% with an overall predominance of sodium (av. 5%) over potassium (av. 3.37%). Similar variations in trace elements viz. Cr (43–171ppm), Ni (<10–73ppm), Rb (53–180ppm), Sr (66–754ppm) and Ce (18–107ppm), are quite apparent. REE distribution pattern indicates prevalence of comparatively low SREE (47–321 ppm) in these granitoids (n=8; except one sample – 809 ppm). Predominance of LREE over HREE (LREE/HREE: 3.09–7.02) and fractionation among LREE (La/Sm<sub>CN</sub>: 2.26–10.06) are distinct. Besides, strong negative Eu anomalies (Eu/Eu\* = 0.29–0.76) point towards evolved nature of granitoids. The compositional diversity of medium to high-K, calc-alkaline granitoids of study area belonging to tonalite–granodiorite–adamellite suite with predominant metaluminous nature (A/CNK: 0.65–1.06; except 1.42 shown by one sample) and presence of biotite±hornblende as the dominant ferromagnesian minerals point towards derivation of magma from upper mantle or lower crustal source with I-type signature. Besides, negative correlation of  $SiO_2$  with MgO, FeO<sup>t</sup>, CaO,  $Al_2O_3$  and positive correlation with  $K_2O$  and  $Na_2O$  indicates highly fractionated nature. In Rb–Nb+Y tectonic discrimination diagram, these granitoids indicate a volcanic arc granite (VAG) tectonic regime at the time of magmatic evolution.

The Rb–Sr whole-rock isochron data of basement granitoid samples have yielded an age of  $2659 \pm 120$  Ma with initial  $^{87}Sr/^{86}Sr$  ratio of  $0.70163 \pm 0.00099$  (MSWD: 3.2). The initial  $^{87}Sr/^{86}Sr$  ratio for these granitoids, within error limits, straddles the model  $^{87}Sr/^{86}Sr$  ratio of 0.7012 for the contemporary depleted upper mantle source. Similarly Pb–Pb ages of these granitoids show  $2638 \pm 94$  Ma with model  $m_1 = 9 \pm 0.5$  and MSWD = 6.8 and are comparable with Rb–Sr ages. These are probably indicating the time of emplacement of these granitic rocks. However, one radioactive granite sample has indicated

Pb–Pb age of ca. 1545±140 Ma with model  $m_1=8.3\pm1.4$  and MSWD= 55. This younger Pb-Pb age with high MSWD value is presumably due to the local redistribution of U and Pb in the sample. Possibly this may be indicative of younger reactivation event in the area. Considering highly labile nature of uranium, such reactivated granitoids form a potential fertile source which may lead to mineralisation under favourable conditions, as already observed at several places in Neoproterozoic Banganapalle sediment cover in unconformity proximal setup.

## **X-RAY DIFFRACTOMETRIC AND ELECTRON PROBE MICRO ANALYTICAL STUDIES ON URANINITE AND FERGUSONITE ASSOCIATED WITH PEGMATOIDS FROM KULLAMPATTI, SALEM DISTRICT, TAMILNADU, INDIA.**

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### **ABSTRACT**

The Suryamalai batholith is emplaced into the high grade granulitic terrain consisting chiefly of biotite-hornblende gneiss. It is the largest batholithic body and extends from Idappadi in the north to Tiruchengodu in the south and Irugular in the east to Kumarapalayam in the west. The batholith was emplaced in the intersection between two major shears consisting of the Moyar-Bhavani-Attur lineament and the Palghat-Cauvery lineament, which together form the Cauvery shear zone. The Neoproterozoic uraniferous rare metal pegmatoids, intruding into granulites at Kullampatti, Salem district, are exposed over an area of about 2 sq km. The pegmatoids show a NE-SW trend and host uraninite and fergusonite.

The uraninite and fergusonite were recovered from the host rock by sequential heavy liquid separation followed by isodynamic magnetic separation. The X-ray diffraction studies (XRD) on the various separates were carried on a Seimens D-500 diffractometer system with the high voltage maintained at 35 kV and the tube current at 20 mA. The Cu  $K_\alpha$  radiation (1.5418 Å) monochromatised using a curved graphite crystal monochromator was used for diffraction. The samples were scanned in the angular range between 4 to 127 degree  $2\theta$  with a step size of 0.01 step and a residence time of 2 seconds per step. The separated grains of uraninite and fergusonite were mounted and analysed on a CAMECA SX-50 Electron Probe Micro Analyzer (EPMA) with four wavelength dispersive spectrometer, with a beam of 4 to 5 micron diameter and beam accelerating voltage of 15 kV and 40 nA current.

The XRD studies of uraninite indicate unit cell dimension ( $a_0$ ) 5.4535 Å and the stoichiometric deviation of oxygen content in its formula unit (FU)  $UO_{2.15}$ . The EPMA studies on five separated uraninite grains show 77.12 to 81.34 %  $UO_2$ , 3.12 to 6.95 %  $ThO_2$ , 4.69 to 6.31 %  $PbO$ , 0.25 to 1.35 %  $CaO$ , 4.02 to 6.29 %  $Y_2O_3$  and 1.77 to 3.52 %  $\Sigma REE_2O_3$ . Initial XRD studies indicated that the fergusonite is metamict. The annealing studies on metamict fergusonite showed the distinct development of a tetragonal phase at 775<sup>o</sup> C with unit cell parameters ranging from  $a_0$  : 5.1595 to 5.1644 Å,  $C_0$  : 10.9408 to 10.9491 Å,  $V$  : 291.2435 to 292.0267 Å<sup>3</sup>, followed by the development of a monoclinic phase at 850<sup>o</sup> C with unit cell parameters ranging from  $a_0$  : 5.0645 to 5.0677 Å,  $b_0$  : 10.9266 to 10.9333 Å,  $c_0$  : 5.2721



to 5.2727 Å, V : 290.8919 to 291.2364 Å<sup>3</sup>,  $\hat{\alpha}$  94.38° to 94.51°. The EPMA studies on fergusonite show 43.24 to 46.92 % Nb<sub>2</sub>O<sub>5</sub>, 0.44 to 1.12 % Ta<sub>2</sub>O<sub>5</sub>, 25.67 to 30.63 % Y<sub>2</sub>O<sub>3</sub>, 7.45 to 11.06 % UO<sub>2</sub>, 9.97 to 11.47 %  $\Sigma$  REE<sub>2</sub>O<sub>3</sub>, 0.80 to 1.79 % CaO, 0.03 to 0.76 % PbO and 1.31 to 2.24 % TiO<sub>2</sub>. The anomalously high concentrations of  $\Sigma$ HREE and ThO<sub>2</sub> in the investigated uraninite and fergusonite indicate the formation of their host pegmatoids under high temperature conditions from melts rich in volatile components. Furthermore, the data also suggest the fractionated and evolved nature of the host pegmatoids.

## **MINERAL CHEMISTRY OF RADIOACTIVE AND ASSOCIATED PHASES FROM NEOPROTEROZOIC UNCONFORMITY RELATED URANIUM DEPOSITS FROM KOPPUNURU, PALNAD SUB-BASIN, GUNTUR DISTRICT, ANDHRA PRADESH, INDIA**

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### **ABSTRACT**

Unconformity proximal uranium mineralization at Koppunuru occurs in basement granitoids and the overlying Banganalalle Formation of Kurnool Group in Palnad sub-basin. The U-mineralization transgresses the unconformity both above and below. Later remobilization of uranium is evident, as they are intermittently intercepted within the sediments overlying the unconformity. Subsurface exploration by drilling intercepted three mineralization bands, viz. Band A and B upto 80m above the unconformity in the overlying Banganalalle quartzite and Band C, mostly sub-parallel to the unconformity and confined to basal conglomerate/grit horizon except a few boreholes where it is transgressing to granitic horizon (<5m).

The radioactive minerals include massive colloform pitchblende and scaly coffinite associated with carbonaceous matter, as well as veins, grain boundary/ fracture fillings in granite and quartzite. The grit/granite radioactive samples, under microprobe, indicate presence of pitchblende, coffinite, and varying complexes like U-Ti-Si-Al, U-Si-Ti-Al, U-Si-Al, U-Si-Al-Pb, U-Si, U-Si-Ca-P and U-Si-Pb-Al (Table 1). This suggests higher activity of alteration processes and remobilization of phases in an open chemical system. The alteration is closely associated with fine-grained zircons appear to be due to the incorporation of UO<sub>2</sub> (upto 2.00 %), ThO<sub>2</sub> (0.03 to 1.51 %) and RE<sub>2</sub>O<sub>3</sub> (0.12 to 3.56 %). Such activities signify the processes of epigenetic fluid/gel related to U-concentration. At increasing depths, possibility of Al- bearing radioactive phases is also envisaged.

The radioactive phases present in the samples reveal negligible to low thorium indicating low temperature phenomena. They are likely to be emplaced by the epigenetic solution / gel rich in U, Ti, Si, Al, Ca, P and Pb, preferably along available spaces as vein, cavity and grain boundary. U-associated sulphides occurring as veins and fracture fills, essentially comprise pyrite, pyrrhotite, chalcopyrite, pentlandite and galena. They have normal chemistry but for subtle variations in minor elements. The pyrite and pyrrhotite are invariably arseniferous and they dominate the sulphides. Thus, it is concluded that the area has potential for multi-episodic epigenetic U-mineralization.

**Table 1:** Microprobe Analyses of U- phases from Gritty quartzite, Koppunuru, Guntur, A.P.

Oxide	Koppunuru						
	Wt. %	Coffinite	Pitchblende	U-Ti-Si-Al	U-Si-Ti-Al	U-Si-Pb-Al	U-Si-Al
UO <sub>2</sub>	69.02	78.58	42.14	51.15	55.03	49.19	62.31
ThO <sub>2</sub>	0.09	0.00	0.31	2.92	0.02	0.00	0.00
PbO	2.49	8.94	1.45	0.12	11.86	0.07	1.92
Al <sub>2</sub> O <sub>3</sub>	0.20	0.68	3.09	2.11	7.19	5.97	1.89
SiO <sub>2</sub>	17.01	3.39	6.96	17.02	21.06	21.02	12.47
P <sub>2</sub> O <sub>5</sub>	1.33	0.00	0.05	0.82	0.56	1.61	8.08
CaO	1.12	1.64	2.60	1.96	0.78	1.82	10.30
TiO <sub>2</sub>	0.07	0.97	30.12	11.89	0.06	0.20	0.10
MnO	0.00	0.06	0.15	0.01	0.01	0.00	0.11
FeO	0.15	0.29	0.76	0.86	0.91	3.81	0.96
Y <sub>2</sub> O <sub>3</sub>	0.85	0.10	0.21	1.36	0.84	1.48	0.37
RE <sub>2</sub> O <sub>3</sub>	1.94	2.40	1.14	3.31	1.65	4.37	0.37
<b>Total</b>	<b>94.27</b>	<b>97.05</b>	<b>88.98</b>	<b>93.53</b>	<b>99.97</b>	<b>89.54</b>	<b>98.88</b>

## HYDROGEOCHEMICAL EXPLORATION FOR URANIUM : A CASE STUDY OF BARAMKELA–SARIA–AMBABHONA AREA, RAIGARH DISTRICT, CHHATTISGARH

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### ABSTRACT

Application of hydrogeochemical techniques in uranium exploration program plays an important role in quick appraisal of an area, especially in soil covered sectors, by utilising rapid and accurate analytical methods of direct measurement of uranium upto ppb level in natural water. Present study deals with the successful utilisation of this tool to delineate the potential target zones in Baramkela–Saria–Ambabhona area, where Mesoproterozoic sediments of Chandrapur and Raipur Groups (Chhattisgarh Supergroup) are deposited over Neoproterozoic to Palaeoproterozoic crystalline basement complex. Arenaceous sediments of Chandrapur Group are exposed as N–S and NE–SW trending ridges in the southern and eastern parts, respectively, whereas Raipur sediments are generally forming low-lying areas and occasionally capped by thick laterite. A major N–S trending fault of nearly 18 km length between Baramkela and Chandrapur separates the sediments of Chandrapur and Raipur Groups. The area has also undergone substantial post-depositional reactivation as indicated by number of N–S, NE–SW and NW–SE trending lineaments/faults/fracture zones, which mostly control the drainage system. Such lithostructural setups are important for uranium mineralisation as evidenced by location of several occurrences elsewhere in north-eastern part of Chhattisgarh basin viz., Chitakhol, Bokarda and Renkhol.

Water samples (n=139) generated over an area of 330 sq.km with sampling density of one sample/~2.5 sq.km from Baramkela–Saria–Ambabhona sector have analysed <1–92ppb U, 0.12–2.63mmhos/cm conductivity, <1–200 ppm SO<sub>4</sub>, 36–475 ppm HCO<sub>3</sub> and 3–549 ppm Cl while pH ranges from 6.4 to 9.1. Other radicals such as Na, K, Ca and Mg analysed upto 210ppm, 99ppm, 229ppm and 98ppm, respectively. Statistical evaluation of processed uranium data (without nugget values) shows 1.31ppb, 1.03ppb and 3.36ppb as mean, SD and threshold (Mean+2SD), respectively. Similarly, U/Conductivity ratio of processed data indicated 1.66, 1.01 and 3.68 as mean, SD and threshold, respectively. A total of 9 anomalous uranium values above threshold have been recorded while U/Conductivity ratio exhibits 11 anomalies after neutralization of effect of total dissolved salts (TDS). The investigations led to the delineation of a distinct NE–SW trending anomalous uranium zone confined within calcareous shale of Gunderdehi Formation (Raipur Group) along Khorigaon–Bilaigarh tract. This zone is also coinciding with NE–SW trending lineament, which is indicative of important role played by faults/fractures in mobilisation and concentration of uranium. This is further supported by multi-element/radical correlation matrix indicating independent nature of uranium. Besides, strong positive correlation of conductivity with Na, Ca, Mg and Cl (0.74–0.9) and moderate correlation with K, SO<sub>4</sub> and HCO<sub>3</sub> (0.61–0.67) signify prevalence of evaporative process in the area. Rotated factor matrix data also shows loading of Na, K, Ca and Cl in factor–1, which suggests evapo-transpiration as one of the important governing process for their concentration in water.

In view of favourable lithostructural setup viz., deposition of Chandrapur and Raipur sediments in rift related basin in an extensional tectonic environment, episodic tectonic pulses leading to deepening of basin, multiple post-depositional reactivation, presence of fertile granitic and rhyolitic provenance, volcanoclasts and tuffaceous rocks (Singhora and Sukhda tuffs) at different stratigraphic layers and a combination of hydrogeochemical parameters and disposition of hydrouanium anomalies along NE–SW lineament unequivocally points towards the possibility of fracture controlled uranium mineralisation in the area.

## **PETROMINERAGRAPHIC STUDY OF OOLITIC PYRITE IN RADIOACTIVE QUARTZ ARENITE OF PHONDA GROUP FROM KALLAMWADI AREA, KOLHAPUR AND SINDHUDURG DISTRICTS, MAHARASHTRA**

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### **ABSTRACT**

Middle Proterozoic Kaladgi Basin located in the Northwestern part of the Dharwar Craton is one of the potential target for unconformity type uranium mineralization. Intensive exploration by Atomic Minerals Directorate, have resulted in locating 64m thick band of uranium mineralization (upto 0.83% eU<sub>3</sub>O<sub>8</sub>) hosted in the Badami arenites of Kaladgi Super Group in close proximity to the basement comprising schistose rocks of the Chitradurga Group, near Deshnur village, Belgaum district, Karnataka. Similar geological set up extends further northwards in the Konkan-Kaladgi region, where the Phonda

Group of rocks (Badamis) are exposed and recorded an interesting horizon of oolitic zone with a lot of sulphides within the Phonda arenites near Kallamwadi. They also have indicated low order radioactivity (0.04mR/hr) at places.

Petrological studies of the representative samples of the oolitic horizon indicate spherical oolites varying in size from 2-2.5mm with finer concentric layerings. In many of these oolitic pyrites, fine quartz grains form the loci around which precipitation of sulphides took place. In periphery of some of these oolites, isolated finer sized anhedral grains of pyrite are also observed, which could be part of another episode of sulphide deposition. The elevated uranium levels in the oolitic horizon indicate the potential of the Phonda Group for uranium mineralization.

The microprobe analysis indicate a decreasing trend of element concentration such as Cu, Co, Ni, Zn, Sb, Ag from the core to the periphery in the oolites. Fe K (alpha) image of oolitic pyrite over an area of 1024X 1024 micron shows a variation of iron concentration from 41.72 to 44.41% and S from 49.06 to 52.78%. There is not much variation in the mineral chemistry between the oolitic and anhedral pyrites, except the As content which is marginally more in the latter. Arsenic content in the oolitic pyrite ranges from 0.01 to 0.09% while in anhedral pyrite it goes up to 0.52%. It is evident from EPMA study that both oolitic and anhedral pyrite appear to be of single episodal sulphide origin. Further it could be possible that pyrite and uranium formed out of two generations.

From the comprehensive petrological and electron microprobe study, it has been concluded that the association of oolitic pyrites and marginally enhanced uranium values is only spatial, coincidental and there is no genetic link between them.

## **INTEGRATED INTERPRETATION OF HELIBORNE GEOPHYSICAL AND REMOTE SENSING DATA TO IDENTIFY POTENTIAL TARGETS FOR URANIUM EXPLORATION IN PARTS OF NORTH DELHI FOLD BELT**

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High resolution heliborne survey which include frequency domain electromagnetic (FDEM), magnetic and gamma-ray spectrometry (AGRS) data, was carried out in parts of Khetri sub basin along the Palsana- Narnaul tract in Sikar and Jhunjhunu districts of Rajasthan and Mahendragarh district of Haryana. The area was flown along N40°W- S40°E direction at 250 m line spacing. High resolution multi-parameter heliborne geophysical survey data in conjunction with satellite imagery and available geological information were analysed to identify new target areas for further exploration. The known potential zones and its vicinity were not considered for evaluation. The process involved knowledge driven analysis through correlation with known geological, geophysical or borehole information.

The study area is mostly soil covered with scanty exposure. Geologically the study area comprises of arenaceous Alwar Group and argillaceous Ajabgarh Group of Middle Proterozoic Delhi Supergroup of rocks. These rocks are intruded by concordant to discordant bodies of acidic and basic intrusive. These metasedimentary sequence has undergone folding and faulting due to polyphase tectonism resulting in development of complex structural fabric. Uranium mineralisations in parts of Khetri sub

basin have been established as structural controlled hydrothermal vein type and closely associated with albitisation & sulphides along the fractures. Presence of sulphides and /or carbonaceous matter in the structurally weaker zones provides the necessary reducing environment for uranium concentration.

Heliborne magnetic data is used for delineation of subsurface geological features. Lineaments were interpreted from Landsat ETM Plus satellite data. Nature of mineralisation encountered in the area indicate faults/ shears are of primary controls. Thus, structural elements such as axial traces of the fold and faults have been interpreted from magnetic and remote sensing data. The locations with presence of AGRS anomalies and known radioactive anomalies associated with structural features have been given priority. The EM data helped to locate the conductors. Since the uranium mineralisation is associated with steeply dipping fractures, the conductors are first located in the coaxial response (frequencies 980Hz and 7001Hz). The EM anomalies located by coplanar frequencies (880Hz & 6006Hz) have been used to establish the continuity of the conductors. Discrete conductors were given more weightage over formational conductors. AGRS data with U/Th ratio >0.8 and U>5 ppm is used define the radiometric anomalies. Ground radioactive anomalies have been used as input to the study. Other relevant geological information was also considered for target delineation.

Based on the defined parameters, nine areas were selected from entire Narnaul-Palsana block for further exploration. Outcome of this study reflect the advantage of integrating all available datasets on a common platform to narrow down the target areas for planning of exploration program effectively.

## **AN INTEGRATED GEOLOGICAL, GEOPHYSICAL AND GEOCHEMICAL APPROACH TO CHARACTERIZE CIRCULAR ELECTRO MAGNETIC ANOMALY, BHIMA BASIN, KARNATAKA**

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### **ABSTRACT**

Typical Versatile Time Domain Electromagnetic (VTEM) response is noticed in south eastern margin of Bhima Basin around Bechabal – Madanur area, Gulbarga district, Karnataka from recently conducted high resolution Heliborne surveys for uranium exploration by AMD. The conspicuous EM anomaly is circular in nature over an area of 50 sq km. The vertical component of time derivative of secondary magnetic field (dBz/dt) pertaining to early and late channel images and the time decay constant (Tau) images deciphered the anomalous circular feature. The conductive depth slices reflected shallow nature of the circular EM response. The total magnetic intensity image (TMI) reflects magnetic low in this part compared to adjacent area. The prominent NW - SE regional magnetic linear disappears in this zone, which is clearly depicted in the tilt derivative image. This is the indication of possible shear zone, which is highly altered in this part. The ternary (U-Th-K) radiometric image of Bhima Basin also indicates very low radio-elemental concentration in this zone, which may be due to soil cover. The Enhanced Thematic Mapper plus (ETM<sup>+</sup>) satellite image (RGB 432) shows darker tone for this feature, suggesting thick soil cover. The basement rocks in general are characterized by lighter tone. Most of the EM conductor response in Bhima Basin is due to presence of shale and overlying

Deccan Trap cover. Therefore, to characterize this typical anomaly, detailed ground check up comprising of geological and geochemical tools were adopted.

Geologically, the study area forms a part of Neoproterozoic Bhima basin on the NE margin of the Dharwar craton, which is sandwiched between the Peninsular Gneissic complex and associated granitoid in south and Deccan Trap in the north. The basement crystalline rocks comprise greenstone / schist belt (Mangalur) of the Hutti Group, present as enclaves in the Peninsular Gneiss that occupies lower contours with peneplained topography and intrusive pink and grey granitoid. Bhima Group of sediments resting unconformably over the basement rocks are represented by purple shale and gray limestone with thin cover of Deccan Traps. The sediments show gentle dip towards west.

The basement rocks are highly weathered within the EM anomalous zone, whereas fresh exposures are available outside the area. The area is thickly soil covered with most of the soil being transported in nature. Along deep cut nalas (NW-SE trends parallel to the major structural grain), soil profiles are developed. The area was divided into two parts i.e. conducting zone (CZ) and non-conducting zone (NCZ; a 2 km buffer zone around CZ) to facilitate easy comparison and interpretation. Geochemical sampling of available media (water/soil/sediments) was carried out to pinpoint geochemical differences between CZ and NCZ.

Owing to the availability and easy sampling techniques, water sampling is preferred as major geochemical tool over others. Mostly, tube wells were targeted as the water is un-contaminated by surficial activity. Besides, few dug-wells and springs were also sampled. A total of 32 water samples (16 each from CZ and NCZ) were analyzed for major cations. The result indicate that, the average conductivity values (4488  $\mu\text{mhos/cm}$ ) of water samples in CZ is four times to that of NCZ (average 1265  $\mu\text{mhos/cm}$ ). Higher concentration of  $\text{Cl}^-$ ,  $\text{Na}^+$ ,  $\text{Ca}^{++}$  and  $\text{Mg}^{++}$  are observed within CZ. Positive correlation of conductivity is observed with  $\text{Cl}^-$ ,  $\text{Na}^+$ ,  $\text{Ca}^{++}$ ,  $\text{Mg}^{++}$  and  $\text{SO}_4^{--}$ . This explains the highly saline nature of water in this part. Close observation indicates that, the soil in the area is black/dark coloured compared to rest of the area, which is red. Basalts, granite-gneiss and schists are the parent materials of the red and black soils and a major source of salts in the soils. Seepage water and over-irrigation are responsible for saline nature of soil. Soil samples (n=32) were collected from B-horizon (along nala cuttings) and also top soil. High CaO (11.26 – 39.2 %) content is observed within CZ, suggesting possible inputs of limestone from adjacent area. These are also characterized by low  $\text{SiO}_2$ ,  $\text{K}_2\text{O}$  and  $\text{Na}_2\text{O}$  contents. The major oxides concentration of soils collected from NCZ are characteristics of gneisses. Stream sediments (n=08) collected from the nala confluence within CZ were analyzed for heavy minerals and petro-mineralogical investigations to infer the provenance. The possibility of buried kimberlite/lamproite body is precluded, as no distinct indicator minerals were seen. The result indicates mixed provenance (gneissic/schistose and sedimentary) from the mineral assemblages. Besides this, portable gamma-ray spectrometry measurements were taken across one profile covering both CZ and NCZ. The result indicate systematic variation of U, Th and K within NCZ due to gneissic country rock and erratic behavior within CZ, indicating presence of transported soils.

Thus, it may be concluded that, the distinct circular EM response in the EM data is not due to presence of any discrete/formational conductor. By integrating above information, presence of thick contaminated (limestone/Deccan Trap) soil and saline nature of ground water, high moisture content underlain by highly weathered basement are responsible for high amplitude EM response.

# **THEMATIC INTEGRATION OF SPATIAL DATA SETS TO DELINEATE FAVOURABLE ZONES FOR URANIUM EXPLORATION IN GANGPUR BASIN, INDIA**

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Surface exploration techniques have been key contributors in discovering mineral deposits over the past three decades; however in the last decade there has been a growing emphasis on integrating remote sensing, geological, geophysical and geochemical exploration techniques to compliment them in identifying concealed deposits. Successful integrated exploration requires putting mappable petrophysical property contrasts in terms of geological and geochemical process that could be associated with different mineralisation environment. The Precambrian Gangpur basin comprising volcanic free sedimentary sequence is considered as a potential geological setting for hosting uranium mineralisation. The Gangpur basin with metasediments of low to medium metamorphic grade classified as the Gangpur Group are known for hosting manganese, limestone and Lead-Zinc deposits. Uranium mineralization is reported in limonitic carbonaceous phyllite and sheared quartzite of Kumarmunda Formation at Jhamankele-Bhalulata areas. Several uranium anomalies have been associated with gossan at Kaedarpani, Jamdra and in ferruginised laterite at Badekachar, Jarmal, Jhagarpur, Kadorpani, Karamabahal, Tetelkela & Kumtinunda.

In the present study geological, geophysical and remote sensing data sets are processed and integrated with other available data to delineate target zones for uranium exploration. Even though direct detection of Uranium mineralisation remains unresolved in exploration strategy, instead it is becoming increasingly instructive to focus on mapping suitable depositional environments. The enhanced satellite imagery is interpreted in terms of thematic layers viz. trend lines, lineaments, faults and geological contacts. The aeromagnetic data is processed and interpreted thematic layers of magnetic breaks and linears from total magnetic intensity (TMI), the reduced to pole (RTP), tilt derivative and amplitude of analytical signal grid images. The radiometric data is processed based on their broad lithology and radio-elemental distribution maps viz. count maps, ratio maps, ternary (K-Th-U) and U/K – U/Th – U images are generated to aid in mapping uranium favourability zones. The favourability image zones with high U/K, U/Th and U counts zones are classified into class based on statistics and anomalous high zones are picked up as uranium favourable locales. The thematic layers of geological contacts, lineaments & faults interpreted from satellite imagery, magnetic linears interpreted from aeromagnetic data and uranium favourability zone extracted from AGRS data are overlaid. Based on spatial association of favourable features few locals are delineated for uranium exploration.

**GEOCHEMISTRY OF ENERGY  
RESOURCES:  
OIL & GAS**



# HYDROCARBON GENERATION POTENTIAL OF OLIGOCENE COALS FROM DILLI RIVER SECTION OF UPPER ASSAM BASIN

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## ABSTRACT

Coals of Permian (Gondwana), Eocene and Oligocene epoch occur in Assam. These coals generally have high sulphur and low ash content. Bulk of Assam coals, however, occurs in Oligocene Baraills. Coals from Tikak Parbat Formation of Barail Group from Dilli area are characterized by low ash, low moisture, high volatile matter and dominant organic sulphur contents. The coals are per-hydrous in nature and are of sub-bituminous rank.

This study has been taken up to determine the hydrocarbon generation potential of Oligocene coals from Dilli River Section. Coal samples were collected from Dilli River Section and their coordinates were noted using a GPS. Coals were analyzed using Rock Eval, a pyrolysis instrument that heats the samples in inert atmosphere to mimic subsurface hydrocarbon generation process in the laboratory. Rock Eval was used to determine hydrocarbons present in the coal ( $S_1$ ), hydrocarbon generation potential ( $S_2$ ), maturity parameter, Tmax and the total organic carbon (TOC). Selected coal samples were extracted using a solvent, dichloromethane, to remove the bitumen present in them. The extracted bitumen was analyzed using GC-MS to determine biomarker maturity parameters. The extracted coal, after removal of bitumen was analyzed using Pyrolysis-Gas Chromatograph-Mass Spectrometer (Py-GC-MS). This instrument pyrolyses the coal at 600°C and the pyrolysed products are analysed online using a GC-MS, to determine the type of hydrocarbons generated by the coals.

The TOC content of the coals ranges from 62-75%, corresponding to sub-bituminous type. Hydrocarbons present in the coals varied from 0.2 to 3.9 Kg/t. The hydrocarbon generation potential of the coals is very high, ranging between 163 and 303 kg/t, with an average of 221 kg/t. However, the production index (PI),  $S_1/(S_1+S_2)$  is less than 0.02 indicating that even though the coals have very high hydrocarbon generation potential, they have not yet generated significant amount of hydrocarbons. This is further confirmed by the maturity parameter ( $T_{max} \leq 424^\circ\text{C}$ ) implying that the coals have not yet reached the oil generation window ( $T_{max}$  around  $435^\circ\text{C}$ ). A plot of PI and Tmax shows that the coals have not yet started expelling the hydrocarbons. Hydrogen Index (HI) is a measure of the amount of hydrogen and carbon in the organic matter that can convert in to hydrocarbons per unit of organic carbon. Dilli coals have HI values between 245-417 mg HC/Corg, indicating that the coals can generate both oil and gas. A plot of HI and Tmax shows that the coals comprise of mixture of Type II & Type III organic matter that can generate both oil and gas on attaining maturity. The plot also shows that coals have not yet reached the oil generation window and are still immature to generate significant amount of hydrocarbons.

Maturity parameters based on saturated hydrocarbon biomarker compounds like hopane/moretane, norhopane / normoretane and diahopane / notmoretane were determined during the GC-MS analysis of the bitumen extracted from coal. These parameters show that the bitumen has generated at very low maturity level of coal.

Distribution of  $C_1-C_5$ ,  $C_6-C_{14}$  and  $C_{15+}$  components in the pyrolysis products obtained during pyrolysis-GC-MS analysis of coals at 600°C, show that these coals will generate paraffinic, high wax oil on attaining maturity. The mass chromatogram of masses 83 and 85, corresponding to alkenes and alkanes, was extracted from the total in current (TIC) chromatogram obtained during above analysis. The mass chromatograms show that significant amount of waxy components are present in the pyrolysis products of coal. The Gas Oil Generation Index (GOGI,  $C_1-C_5 / C_{6+}$ ) for the coals is also quite low (~0.12). This implies that coals will mainly generate waxy, liquid hydrocarbons with some amount of gas.

Amongst the compounds, n-octene, m-+p-xylene and phenol, generated during pyrolysis of coal, the latter two constitute approximately 90%. These two compounds are derived from woody, lignin containing land plants, i.e. vitrinite. Distribution of these compounds shows that the coals are derived from Type III organic matter. The ratio m-+p-xylene / n-octene is used for determining the type of kerogen. Values more than 1.2 indicate Type III kerogen and values less than 0.3 indicate Type I kerogen. This ratio is more than 1.5 for Dilli coals, further confirming that they predominantly consist of Vitrinite rich, Type III kerogen. It can be concluded that coals from Dilli River Section are comprised of predominantly vitrinitic, Type III organic matter that is too immature to generate any hydrocarbons. However, on attaining maturity, they will generate significant amount of waxy oil and some gas.

## **APPLICATION OF ISOTOPE RATIO ANALYSIS OF NATURAL GAS IN SOLVING OILFIELD PROBLEM RELATED TO ANNULAR PRESSURE BUILDUP**

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### **ABSTRACT**

The problem of annular pressure buildup was observed in several wells in OIL's hydrocarbon producing wells. This study was taken up to identify the source of the casing gas and annulus gas by correlating it with the gas normally produced through the tubing, referred to as tubing gas. The correlation was done using compound specific stable carbon isotope ratio of individual components of the gases. Several parameters derived from the stable carbon isotope ratio,  $\delta^{13}C$ , of individual components of natural gas can be used to determine the origin, maturity and biodegradation of the gas. Further, biogenic and thermogenic gases can also be differentiated using carbon isotope values.

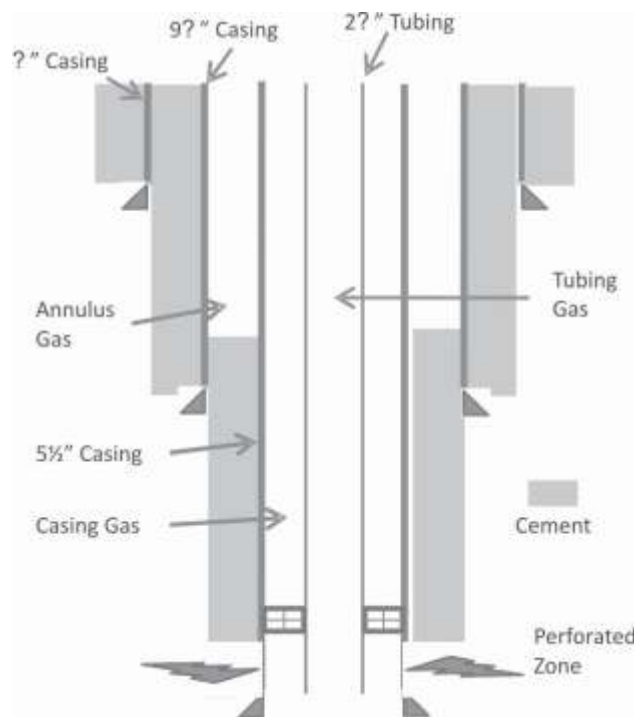
Natural gas samples were collected from six wells from Naharkatiya, Samdang, Barekuri, Kusijan and Baghjan fields. Gas samples collected from tubing, annulus and casing were analyzed using Gas Chromatograph Isotope Ratio Mass Spectrometer.

Detailed isotope ratio analyses of gases from different wells has shown that

- Tubing, casing and annulus gases for well Naharkatiya A are identical
- Tubing, casing and annulus gases for well Samdang A are identical
- Tubing, casing and annulus gases for well Barekuri A are identical

- Tubing and casing gases for well Kusijan A are identical. Annulus gas for Kusijan A is a mixture of tubing gas and biogenic methane generated at shallow depths. Annulus gas from Kusijan B is similar to tubing and casing gas from Kusijan A
- Tubing and casing gases for Baghjan A well are identical. Annulus gas for Baghjan A is a mixture of tubing gas and biogenic methane generated at shallow depths.

The above results show that, in all the wells, the produced gas has reached the annulus either through channeling through the cement between 5½” and 9½” casing or the 5½” casing is damaged at some point causing the casing gas to move to the annulus. Further, for wells Kusijan A and Baghjan A, the 9½” casing is also probably damaged at shallow depths enabling the mixing of the gas collected in the annulus with biogenic methane present in the formation at shallow depths.



**Figure 1:** Design of a hydrocarbon producing well

## **DELINEATING GAS-HYDRATES: FUTURE MAJOR POTENTIAL ENERGY RESOURCE OF INDIA**

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### **ABSTRACT**

Gas-hydrates have attracted the explorationists because of their abundant natural occurrences and huge energy potential, and thus envisaged as a feasible major energy resource of future. The bathymetry, seafloor temperature, sedimentary thickness, rate of sedimentation, geothermal gradient,

total organic carbon content indicate shallow sediments along the continental margin of India to be good host for gas-hydrates. The most commonly used marker for gas-hydrates is a bottom simulating reflector or BSR, which is a physical interface between gas hydrate-bearing sediments above and free gas saturated sediments below. From the analysis of seismic data, gas-hydrates have been recognized in the Krishna-Godavari, Mahanadi and Andaman basins in the Bay of Bengal, and in the Kerala-Konkan, and Saurashtra basins in the Arabian Sea. The Kerala-Laccadive basin in the western and the Cauvery basin in the eastern margin of India are also found to be prospective. We have computed the reflection strength, instantaneous frequency, blanking and attenuation ( $Q^{-1}$ ) to seismic data along the Indian margin, and demonstrate that these seismic attributes can be used for characterizing sediments containing gas-hydrates and free-gas below. The seismic velocity of pure gas-hydrates is much higher than that of host rock. Therefore, presence of gas-hydrates increases the velocity of sediments, whereas underlying free-gas reduces the P-wave velocity. We have used the seismic velocity anomaly against the background trend for delineating the zones of gas-hydrates and free-gas across the BSR. We have translated the velocity anomaly in terms of saturations of gas-hydrates and free-gas by employing the rock physics modeling. Application of these approaches will be presented to seismic data in different basins along the Indian margin for the identification and quantification of gas-hydrates.

## **INVESTIGATIONS OF HYDROCARBON SEEPAGES IN HIMALAYAN FOOTHILLS USING MOLECULAR AND ISOTOPIC STUDIES**

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### **ABSTRACT**

Exploration activity in Himalayan foothills started since the inception of ONGC in 1956 with the drilling of its first exploratory well in Jwalamukhi region in Himachal Pradesh. Many gas seepages have also been reported and investigated in this region from time to time. Natural gases studied from exploratory wells JMI-1, JMI-7, JMI-8 and Nurpur-1 and gas seepages from Gopalpur (Distt. Kangra) and Ghutliar (Distt. Una) are indicated to be of high maturity and thermogenic nature with high nitrogen content which are inferred to be generated at deeper sources ( $\delta^{13}C$  -31 to -33 ‰). Alternatively intermittent gas seepages reported from Pong Dam area (Distt. Kangra) and seepage from village Jambal within the same area are indicated to be of bacterial origin ( $\delta^{13}C_1$  -60 to -65 ‰) which was established through their molecular compositions combined with stable isotopic studies. Presence of gas seepages in this tectonically complex area may have significant consequences for hydrocarbon exploration. It is established that precise molecular and isotopic studies can distinguish between bacterial gas seepages from high maturity thermogenic gases in exploratory wells.

# PETROLEUM SYSTEM MODELING IN YANAM SHALLOW OFFSHORE AREA OF KG BASIN, INDIA

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## ABSTRACT

A 2D- Petroleum System Modeling study along one N-S seismo-geological cross section, passing through two drilled wells YSA and YSB, has been carried out to model paleo-history reconstruction and to assess hydrocarbon generation, migration and accumulation in Yanam shallow offshore area of KG Basin.

The geochemical data of two L.Jurassic-E.Cretaceous Golapalli oils in study area indicate the source input to be fresh water lacustrine organic matter. The C<sub>29</sub> sterane maturity values of these oils suggest lower than peak oil generation maturity. The oil-source correlation studies show that oils are co-relatable with early to late Cretaceous source rock sequences.

The 2D-modeling was carried out on integrated Petroleum System Modeling software Petromod from M/s IES, Germany. Source rock sequences were identified based on the source rock data from drilled wells and source rock parameters (TOC, HI) were assigned accordingly. A generic type III kinetic model, which fits to all source rocks, was assigned for conversion of kerogen into hydrocarbon. The kinetic model is based upon Burnham (1989)\_T III, where activation energy range is 46-68 K cal/mole with maxima at 52 K cal/mole and HI is 160. Thermal history calibration was made using observed corrected BHT values and observed VRo values from wells YSA and YSB. A good correlation of BHT and modeled temperatures was observed by setting the present day heat flow to 52mW/m<sup>2</sup> at YSA and 42mW/m<sup>2</sup> at YSB. A heat flow trend was assign to 2D model by taking into account the heat flow of YSA for southern part and YSB for the northern part.

The modeling results indicate that towards deeper northern part (towards well YSB) of the studied section the deepest studied L.Jurassic-E.Cretaceous Golapalli source rock is in wet gas generation stage. It has attained the critical moment (time of 50% kerogen conversion) at 80 Ma, with present day transformation ratio (TR) of more than 80%. The Albian source rock is in late gas generation stage and has attained the critical moment at 36 Ma, with present day transformation ratio of 65%. The bottom part of L. Cretaceous source rock layer is in late oil generation stage. It has attained the critical moment at 22 Ma, with present day transformation ratio of 57%.The upper part of L. Cretaceous source rock layer is in main oil generation stage with present day transformation ratio of 47%. Paleocene source rock is in early oil generation stage with present day transformation ratio of 1%.

In shallower southern part, towards well YSA, the E. Cretaceous Rift fill source rock is in late oil generation stage and has attained the critical moment at 3 Ma, with present day transformation ratio of 60%. The lower and upper part of L. Cretaceous source rocks are in early to main oil generation stage with present day transformation ratio of 17% and 7% respectively.

2D- Petroleum System Modeling indicates the possibility of hydrocarbon accumulations on top of Golapalli Formation at basinal highs. The results from source rock tracking indicate that the accumulation at the top of Golapalli Formation around well YSA is mainly contributed from E.Cretaceous -Aptian rift-fill source sediments with minor contribution from L.Jurassic-E.Cretaceous Golapalli source rock.

## **LIGHT HYDROCARBON GEOCHEMISTRY OF OILS/CONDENSATES OF KALI-KUTHALAM AREA, CAUVERY BASIN**

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### **ABSTRACT**

The lighter fractions of oils/condensates ( $C_5$ - $C_7$ ) provide valuable information regarding origin, maturity, oil-oil correlation and secondary alterations of oils and condensates in a basin. Study of these compounds, known as light hydrocarbons (LHs), is helpful in geochemical characterization of high maturity samples where biomarkers are very low or absent. A technique has been standardised to analyse, identify and fingerprint light hydrocarbons. Further, this technique has been successfully applied in oils and condensates of Kali-Kuthalam fields.

Fifteen oil and condensate samples from Lower Cretaceous Andimadam Formation across Kali-Kuthalam fields, Tranquebar sub-basin, Cauvery Basin were studied for their light hydrocarbon based parameters. Light hydrocarbon based ratios, namely,  $K_1 = (2\text{-MH} + 2,3\text{-DMP}) / (3\text{-MH} + 2,4\text{-DMP})$  and  $K_2 = (2,2\text{-DMP} + 2,3\text{-DMP} + 2,4\text{-DMP} + 3,3\text{-DMP} + 3\text{-Ethylpentane}) / [\{2\text{-MH} + 3\text{-MH}\} + \{1,1\text{-DMCP} + 1,3\text{-DMCP (cis and trans)}\}]$  suggest that all fluids belong to a common source. Star diagram  $C_7$  OCSD (oil correlation star diagram) of light hydrocarbon components also suggests that the oils and condensates belong to a common family. Star diagram  $C_7$  OTSD (oil transformation star diagram), ternary diagrams ( $nC_7$ , MCH, Toluene; and  $nC_7$ , monobranched, polybranched alkanes) and cross-plot (Toluene/ $nC_7$  vs  $nC_7$ /MCH) suggest that some oils and condensates have been mildly transformed by water washing and evaporation but no biodegradation has occurred.

Ternary diagram of  $RP_6$  (Toluene+Methyl cyclohexane),  $RP_5$  (Cyclopentanes) and  $RP_3$  (Isoalkanes) based on light hydrocarbon components suggests that oils and condensates have been generated from mixed terrigenous/humic and mat forming algae and bacteria. The light hydrocarbon based calculated temperature of expulsion for studied samples of Kali-Kuthalam area ranges from 128.4°C to 134.4°C which suggests that both oil and condensates were generated under moderate thermal stress. The calculated maturity based on light hydrocarbons thus implies that all fluids were generated within oil-window and condensates were not generated by thermal cracking of oil at high maturity.

# PETROLEUM GEOCHEMISTRY OF OILS FROM NEW EXPLORATORY WELLS IN WESTERN OFFSHORE BASIN, INDIA

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## ABSTRACT

Western Offshore Basin is a pericratonic rift basin in the western continental shelf. It is divided into six blocks. New exploratory oils were discovered last year in three of these blocks, namely Tapti-Daman, Heera-Panna-Bassein and Deep Continental Shelf block. Molecular level geochemical studies were carried out on these exploratory oils, to correlate them with the producing oils from their respective blocks.

Ten new oil finds from prospects C-26, B-12, EDPO, B-163A, B-121, D-1 and D-18 have been taken for the study. Cross plot of API versus depth reveals that the Daman and Panvel (U.Oligocene) formation oils are condensates and the rest are light oils. The Daman and Panvel oils are characterized by low pour points (<0°C) and low wax content (<1.2 wt%). Panna, Bassein, Mukta and Ratnagiri oils have higher pour points (>6 °C) and higher wax content (>15 wt%).

Biomarker and stable carbon isotopic composition reveals that the Daman oils of well nos. C-26-A and B-12-C are generated from predominantly terrigenous source facies deposited in sub-oxic environment. The C-26-A oil shows moderate maturity whereas B-12-C oil shows peak oil maturity of its source rocks. Oils of wells B-163A-C, B-121-D and EDPO-E are derived from mixed terrigenous-marine source facies with varying amount of land plant input deposited in suboxic marine environment. The oils show moderate maturity except for EDPO-E oil which shows peak oil maturity. The Deep Continental Shelf block oils D-1-E (object I), D-18-G (object III and IIa) are derived from mixed terrigenous source deposited in anoxic environment. The oils show peak oil maturity.

Oil – oil correlation of oils from B-12 structure show different hopanes and steranes fingerprints and are not correlatable. The oil of B-12-C shows higher maturity than oil from B-12-B. Two objects from well EDPO-E show different mass fragmentograms. Oils from D-1 structure are genetically similar and have been generated from organic matter at peak oil maturity.

# **EVIDENCE OF MICROBIAL ANOMALIES FOR HYDROCARBON EXPLORATION IN JAMNAGAR SUB-BASIN, SAURASHTRA, GUJARAT, INDIA**

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## **ABSTRACT**

For the hydrocarbon exploration microbial techniques have been used to delineate the anomalous zone in Jamnagar sub-basin, Saurashtra, Gujarat. The micro organisms especially propane and butane oxidizing bacteria usually associate with subsurface hydrocarbon accumulations. In the present study propane oxidizing bacteria has been considered as indicator microbes. Two distinct zones of anomalous bacterial activity have been detected in the study area, indicating hydrocarbon microseepage. The adsorbed light gaseous hydrocarbons analyses on these soil samples show the presence of high to moderate concentrations of methane, ethane, propane, iso-butane, n-butane, iso-pentane and n-pentane respectively. On the basis of microbial prospecting and adsorbed soil gas studies the Jamnagar sub-basin, is found to be positive a prospect for hydrocarbons.

## **HYDROCARBON MICROSEEPAGE PREDICTION BY NEAR-SURFACE GEOCHEMISTRY FOR PETROLEUM EXPLORATION**

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## **ABSTRACT**

Near-surface hydrocarbon seeps have led to the discovery of many important petroleum producing areas. Petroliferous basins exhibit different type of near-surface indication, but the hydrocarbon seepage to surface is not always detectable with conventional seep detection methods. The near-surface indication of migrating hydrocarbons provides the petroleum systems about source, maturation, migration, and specific prospect hydrocarbon charge. Geochemical methods provide important tools for understanding the petroleum system and for assessment and prospect evaluation of the basin. The rate and volume of hydrocarbon seepage to the surface greatly control near-surface geological and biological responses, and thus are the best method of sampling and analysis to detect hydrocarbon leakage effectively. The near-surface geochemical anomaly represents the petroleum migration pathway, which can range from short distance vertical migration to long distance lateral migration. To predict subsurface petroleum properties, interpretation of geochemical data must recognize many potential problems like recent organic matter input, transported hydrocarbons, bacterial alteration, mixing, contamination, and



fractionation effects. The geochemical data integrated with geological and geophysical data gives double success rate in petroleum exploration. This method has been applied to understand Petroleum system and delineate prospects area in Mizoram of Assam-Arakan petroliferous Basin.

Mizoram is a geologically complex area with repeated folding and thrusting coupled with steep sub-surface dips of the strata. Therefore, seismic data alone may not be able to reduce the risks of exploration. Near-surface geochemical data have raised the confidence level with integration of seismic data and to reduce such risks. Soil core samples were collected and analyzed for light hydrocarbon gases (methane, ethane, propane & butane) by using adsorbed soil gas technique. The light hydrocarbon and stable carbon isotopes signatures indicate generation of gases from thermogenic source and their condensate nature. Large-magnitude hydrocarbon seeps occurring in close correspondence to maple anomalies occur within an anticline and ravine, suggesting a zone of increased fracture permeability. The high-concentration samples do fall within the Aibawk, Chippir and Sirchip anticline boundaries of the structural high that forms the trap and might be the prospects areas for future hydrocarbon exploration.

## **APPLICATION OF ADSORBED SOIL GAS AND MICROBIAL METHODS FOR DETECTION OF HYDROCARBON MICROSEEPAGE IN NEAR SURFACE SOILS OF KRISHNA-GODAVARI BASIN, ANDHRA PRADESH, INDIA.**

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### **ABSTRACT**

Surface adsorbed gas surveys and geo-microbiological surveys are known techniques of petroleum exploration and aim towards risk reduction in exploration by way of identifying the areas warm with hydrocarbons and to establish intense exploration priorities amongst the identified warm areas. The present investigation aims to explore correlation between the adsorbed gas distribution pattern with the distribution of the counts of methane, ethane, propane and butane microbial oxidizers in the sub soil samples to establish the role of the latter in identifying the upward migration of hydrocarbons especially in the known petroliferous Krishna-Godavari Basin, India. A total of 135 soil samples were collected near oil and gas fields of Tatipaka, Pasarlapudi areas of Krishna Godavari Basin, Andhra Pradesh. The soil samples were collected from a depth of 2 - 2.5 m. The samples collected, were analyzed for indicator hydrocarbon oxidizing bacteria, adsorbed light gaseous hydrocarbons and carbon isotopes ( $\delta^{13}\text{C}_{\text{methane}}$  and  $\delta^{13}\text{C}_{\text{ethane}}$ ). The microbial prospecting studies showed the presence of high bacterial population for methane ( $5.4 \times 10^6$  cfu/gm), ethane ( $5.5 \times 10^6$  cfu/gm), propane ( $4.6 \times 10^6$  cfu/gm) and butane oxidizing bacteria ( $4.6 \times 10^6$  cfu/gm) in soil samples. The light gaseous hydrocarbon analysis show that the concentrations were 82 ppb, 93 ppb, 134 ppb, 187 ppb and 316 ppb of  $\text{C}_1$ ,  $\text{C}_2$ ,  $\text{C}_3$ ,  $\text{nC}_4$  and  $\text{nC}_5$ , respectively, and the carbon isotopic composition of  $\delta^{13}\text{C}_1$  of the samples ranges between  $-36.6\%$  to  $-22.7\%$  (Pee Dee Belemnite) values indicate thermogenic origin, which presents convincing evidence that the adsorbed soil gases collected from these sediments are of thermogenic origin. Geo-microbial prospecting method and adsorbed soil gas and carbon isotope studies have shown good

correlation with existing oil/ gas fields of K.G basin. Microbial surveys can independently precede other geochemical and geophysical surveys to delineate areas warm with hydrocarbons and mapped microbiological anomalies may provide focus for locales of hydrocarbon accumulation in the K.G basin.

## **GEOCHEMICAL SIGNIFICANCE OF PETROLEUM ASPHALTENES AS MATURITY AND SOURCE INDICATORS**

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### **ABSTRACT**

In the last few years asphaltene have acquired immense interest for hydrocarbon exploration, since they possess structural features of the related source rock kerogens. The use of asphaltene from crude oils may help to overcome the lack of source rock samples in basin analysis when reliable predictions for the generation of hydrocarbons are required. Potential source rocks are described in terms of quantity, quality and level of thermal maturity of organic matter, but pertinent source rock information is frequently absent because exploratory drilling do not reach deeply buried source facies. Even if the source is reached, samples are often inappropriate for reliable oil-source rock correlation due to low maturity or organic facies variation. Especially passive margins are amongst the most prospective areas for future hydrocarbon exploration and the assessment of their potential requires understanding the processes involved in continental break-up and margin development.

Asphaltene separated from two different crude oils from upper Assam basin, India having different geological origins, namely DK (Eocene) and JN (Oligocene-Miocene) were pyrolysed at 600°C in a PY-2020iD double shot pyrolyzer and the products were analyzed by gas chromatography-mass spectrometry (GC/MS) especially for the generated Methyl-naphthalenes and Methyl-phenanthrenes. Both the asphaltene produces aliphatic as well as aromatic compound classes. Methyl-naphthalenes and Methyl-phenanthrenes were identified by using reference chromatograms and literature data and their distributions were used to assess thermal maturity of the asphaltene. The ratios of  $\beta$ -substituted to  $\alpha$ -substituted isomers of both Methyl-naphthalenes and Methyl-phenanthrenes revealed higher maturity of the JN asphaltene than that of the DK asphaltene. For both the asphaltene the abundance of 1-methyl-phenanthrene dominates over that of 9-methyl-phenanthrene showing the terrestrial nature of the organic matter. Based on the distribution pattern of n-alkanes in pyrolysed product of Asphaltene and their respective crude oils, it was concluded that crude oil and asphaltene originated from the same source and asphaltene are the unconverted parts of kerogens.

# **APPLIED GEOCHEMISTRY IN ENVIRONMENTAL STUDIES**

# **SEDIMENTOLOGY, GEOCHEMISTRY AND PALEOSOL CONTROL OF ARSENIC POLLUTION IN THE BENGAL DELTA PLAIN UNDERGROUND AQUIFERS**

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## **ABSTRACT**

Arsenic contamination of the shallow aquifers in the Bengal Delta Plains has caused unprecedented misery to the highly populated regions of India and Bangladesh. Many parts of SE Asia, northern Asia, parts of South America and parts of North America. are also affected by this menace. In most cases, such contaminated aquifers are confined to fluvio-deltaic regions, especially concentrated in the tropics and less commonly in the sub-tropical regions. Carcinoma of skin, blood cancer, skin rashes with bleeding lesion, deformities of limbs, intestinal hemorrhage and brain damage are caused by prolonged use of arsenic laden ground water obtained from shallow hand pumps. Mitigation and providing arsenic free water to its people is a formidable challenge to health authorities.

While a large number of scientific as well as charitable organizations are doing extensive research on arsenic filters of various size, shape and efficacy, many geoscientists are engaged in understanding the cause of arsenic release in the shallow aquifers in regions where surface water is virtually free of this poison. While it is well known for a long time that small amount of arsenic reaches the local aquifers through industrial effluents and phosphate fertilizer used in the rice field, the cause of its distribution on a regional scale has been understood only recently. Extensive analysis of sediments and water on a regional studies have shown that large scale arsenic contamination is of geological origin and therefore show a remarkable heterogeneous distribution pattern. The cause of this heterogeneity is still not satisfactorily resolved. In order to study the cause of this heterogeneity, our research group studied more than 15 thousand wells across a little more than 100 Km<sup>2</sup> area in parts of North 24-Parganas in West Bengal. Detailed logging of nearly 50 wells reveal that distribution of As-pollutant is governed by subsurface sediment architecture and is influenced by the redox state of the aquifer. While arsenic release in the groundwater is geochemically controlled by the reducing environment of the shallow aquifers, geological and geochemical analysis of all the borehole cores suggest a primary influence of the contiguous paleo-interfluves and paleosol horizons. Water analysis indicates that the many shallow aquifer (<70 mbgl) are unpolluted by arsenic (<10 ìg/L) because these are capped by an impermeable paleosol of red clay formed during the LGMP (the last glacial maximum) at depths between 16 and 24 mbgl. It can be demonstrated that the LGMP protects the aquifer from vertical recharge that might carry As-rich water or dissolved organic matter which drives reduction of the sedimentary iron oxide and thereby release arsenic to the groundwater. In the flanking paleo-channels, the palaeosol is absent, so that aquifers are invaded by arsenic and dissolved organic matter which makes the, paleo-channel groundwater severely polluted by arsenic (10 to >50 ìg/L). All these years the role of paleosols and, in particular, the LGMP, has been overlooked as a control on groundwater flow and pollutant movement in deltaic and coastal aquifers worldwide. All models of pollutant infiltration in such environments must therefore include the appreciation that, places where the LGMP (or other paleosols) underlies the surface soil, water recharge is deflected laterally downward towards the inter-fluvial paleo-channel regions. The aquifer beneath the paleosol remains unpolluted for decades until lateral flow from the inter-fluvial region moves laterally and contaminates it.

# ADVANCED COST-EFFECTIVE SURFACE GEOCHEMICAL TECHNIQUES FOR OIL/GAS/URANIUM EXPLORATION, ENVIRONMENTAL ASSESSMENTS AND PIPELINE MONITORING – A TEMPLATE FOR INDIA

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## ABSTRACT

Advanced geochemical soil gas methods have been successfully developed for the exploration of oil/gas/uranium and for environmental assessments. Application of these cost-effective technologies in India can substantially reduce exploration risk while accelerating the development of oil/gas/uranium onshore resources. A reliable and effective monitoring system using geochemical soil gas surveys ensures that CO<sub>2</sub> Enhanced Oil Recovery operations as well as CO<sub>2</sub> sequestration projects are safe and acceptable for the disposal of CO<sub>2</sub>. Soil gas surveys along with other technologies can also be applied for monitoring of oil/gas pipelines for leakage, especially those that are old or pass through populated regions.

The geochemical prospecting for reservoirs of oil and gas by analyzing the surface soils for traces of hydrocarbons (microseeps) has led to major discoveries in the last 10 years. Major advances in computerization, microelectronics, global positioning and analytical technologies as well as interpretation methods have contributed greatly to the acceptance of geochemistry as a major tool for oil and gas exploration. Companies are looking for new cost-effective technology that will reduce the high financial risk of exploration while increasing the discovery ratio. Countries like India are also looking for methods that will accelerate development of their resources. Without geochemistry, the average success ratio for rank wildcats (i.e. drill holes at least 10 miles from the nearest producing well) will remain very low, about 10-15%.

Advanced soil gas survey methods are important tools in the exploration of hydrocarbon reservoirs because they measure hydrocarbons directly, unlike seismic and indirect geochemical approaches. Not all geochemical methods are created equal. Light hydrocarbons naturally escape as **microseeps** from reservoirs and travel vertically to the surface where they can be detected and analyzed by the gas chromatograph. Concentration patterns or surface anomalies of these **microseeps** can be reliably related to petroleum/gas accumulations at depth. Moreover, Petro-Find sophisticated technology can ascertain whether a discovered reservoir is charged with oil, gas condensate or natural gas and whether the oil is light or heavy.

The keys to cost-effective soil gas surveys include:

- Highly mobile and fast sampling system with small environmental imprint to access populated areas, fields in crop or fenced, forests and difficult terrains;
- The use of probes, vials and syringes with very low leakage rates;
- Evacuation of sample vials to high vacuum;
- Accurate soil sampling using non-plugging probes for sampling depth of at least a meter to avoid biological activity at the near surface;

- Use of passive samplers for wet areas;
- Accurate and fast analysis by high end gas chromatograph equipped with FID/TCD detectors, auto-samplers and back-flushing;
- Good interpretation including close coordination with seismic and geology.

Soil gas surveys using helium and hydrogen as pathfinders can accelerate development of uranium/thorium for countries like India. Exploration for such deposits is usually high risk because they are usually low-grade and are hard to find at depth. Conventional exploration using geophysics and drilling can be difficult, highly inefficient, environmentally unfriendly, costly and time-consuming. The soil gas method is based on the sampling and analysis of helium and hydrogen in soils that have migrated from the uranium deposits and deep-seated faults, respectively. Helium, a product of uranium decay, is a direct indicator whereas hydrogen, produced from the radiolysis of water and Redox reactions, is an indirect pathfinder. The measurement of helium and hydrogen in soils requires special care because of their volatility.

Soil gas surveys could provide an important tool for environmental assessments in India. The feasibility of injecting anthropogenic CO<sub>2</sub> underground for sequestration or to enhance oil production is largely dependent on whether CO<sub>2</sub> remains trapped over a long period of time and does not migrate to the surface. It is important to assess the CO<sub>2</sub> concentrations in soils because of the possible harm to humans, flora and fauna. Soil gas surveys can measure concentrations of CO<sub>2</sub> and light hydrocarbons in soils to monitor whether such gases have escaped to the surface. Baseline studies should be conducted prior to injection of CO<sub>2</sub> followed by repetitive surveys over a long period of time. A reliable and effective monitoring system at the surface is an important part of making geologic sequestration a safe and acceptable method for the permanent disposal of CO<sub>2</sub>.

Under development is a unique system for natural gas and oil pipeline monitoring that could be of interest to India. It combines our unique capabilities in monitoring leakage with soil gas surveys and sophisticated infrared thermography that detect different gases according to their wavelengths. Unlike the crude hand-held gas detectors that can detect only massive leaks, this system would be able to detect and pinpoint incipient leaks that usually precede catastrophic events. A cost-effective monitoring system would not only assure the integrity of pipelines, it would save on transmission costs.

## **MUNICIPAL SOLID WASTE - A POTENTIAL LATENT RESOURCE FOR NON-CONVENTIONAL ENERGY**

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### **ABSTRACT**

Municipal Solid Waste (MSW) is generated in large quantities, at about 120, 000 metric tons per day in India, with daily per capita generation ranging from about 100 g in small to 500 g in large towns and with the per capita generation increasing at a rate of 1-1.33% annually. The MSW in India is collected primarily by sweeping and deposited in waste storage bins; then transported and dumped in

low-lying marshy ground on the outskirts urban areas, where it normally undergoes decomposition anaerobically, which releases various gases mainly methane ( $\text{CH}_4$ ) to atmosphere.  $\text{CH}_4$  is known as one of the important greenhouse gases and has about 15-30 times greater infrared absorbing capacity than that of Carbon dioxide ( $\text{CO}_2$ ). MSW comprises of biodegradable materials ranging from 40 to 60% and inert material (30 to 50%) and recyclable materials (paper, plastic, glass and metals) being relatively in low quantities. The MSW of India differs from that of developed countries in composition of biodegradable and recyclable components. The MSW disposal methods in India mainly include landfilling, aerobic composting, and some to energy enterprises – i) incineration, ii) RDF (Refuse Derived Fuel) and iii) biomethanation. The MSW can be converted to non-conventional energy, which is an eco-friendly method of disposing the MSW and is sustainable, because the MSW generation is never stopped. Otherwise, the unsanitary methods adopted for MSW disposal in India, cause serious environmental health problems and its open dumping facilitates breeding of disease vectors such as flies, mosquitoes, rats and other pests (CPCB, 2000). The MSW (management and handling) rules 2000, issued by Ministry of Environment Forests (Government of India) states that the municipal authorities shall adopt suitable technologies to make use of MSW to minimize burden on the open landfills. The biodegradable waste can be processed aerobically by composting and vermicomposting and anaerobically by biomethanation. The non-biodegradable waste can be processed for recovering energy through pelletisation, the process known as RDF, and the project is known as CDM (Clean Development Mechanism) Project. Such projects have been initiated at various cities in India to recover energy by RDF process from MSW, in Andhra Pradesh at Vijayawada, Guntur, Hyderabad and Karimnagar, utilizing MSW of 50 to 700 t/day, and similarly biomethanation plant at Vijayawada and Chennai (Koyambedu). There are 16 CDM projects recovering energy from MSW in India, of which 11 are RDF based and one is based on biomethanation. However, there are no projects on landfill gas recovery as the case at New Jersey (USA), where decade's worth of MSW buried in landfills are providing electricity energy to thousands of homes; there are 21 landfills in New Jersey, where  $\text{CH}_4$  gas produced anaerobically by decomposition of MSW is used as fuel to generate electricity. There are 455 landfills according to Environmental Protection Agency (EPA) across USA that uses the  $\text{CH}_4$  gas from MSW to generate electricity. The landfills are seen as potential New Age energy plants; because, it can be combined with wind and solar power to supplement methane energy and create a steady source of energy. Therefore,  $\text{CH}_4$  gas harvested from MSW landfills is one of the key renewable energy sources. The gas is used as fuel to drive generators producing energy. Organic waste disposal at the landfill is prohibited in India, and it is made mandatory to treat the organic waste and is not to be put in landfills, hence there does not exist the potential for landfill gas generation. Incineration of thousands of tons of MSW and industrial waste converts waste into heat and electricity in Denmark; the incinerators, being known as 'waste to energy plants'. Use of such energy has not only reduced the country's energy cost and reliance on oil and gas, but also benefitted the environment diminishing the use of landfills and cutting  $\text{CO}_2$  emission. With these innovations, Denmark now regards MSW as clean alternative energy, and now has 29 such plants, serving 98 municipalities in a country with 5.5 million people, and ten more are under construction. There are about 400 such energy plants across Europe. Emissions from the plants in all categories have been reduced to just 10 to 20% of levels allowed under the EU's standards for air discharges. In India, an incinerator capable of generating 3.75 MW power from 300 TPD MSW was installed at Delhi (Timarpur) in 1987. However, it could not operate successfully due to low net calorific value of MSW; making the plant idle and the investment is wasted. India may have to import suitable technologies of 'waste to energy plants' to convert the waste to energy successfully, which may prevent burning of MSW in open landfills and air contamination.

# **LATEST TRENDS IN HYDROGEOCHEMICAL RESEARCH IN INDIAN PERSPECTIVE**

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## **ABSTRACT**

The article is prepared, in tune with the topic of the symposium, to focus on the status of research in water chemistry in India. It is not a scientific paper but a write-up chronicling the various aspects of scientific study including roadblocks milestones etc. India, in the recent years had taken big leap in diverse fields of geochemistry research. Advancements in hydrochemistry are not commensurate with the requirement and on par with advanced countries. Though many scientists are making efforts and publishing in high rated journals, path breaking findings which could attract awards in the international arena are not forthcoming. Of late deterioration in water quality is taking place enormously, up to date knowledge and data base development is very essential to monitor and control water contamination. Apart from carrying out basic and classical studies, it is high time that India makes advanced research in water chemistry fields employing all available latest facilities. In the article the existing scenario and drawbacks which are hindering the rapid progress in water quality research are depicted with a view to enlighten the scientists, administrators policy makers etc. Infrastructure development, capacity building, introduction of specialized courses in universities, multi-discipline research etc., could help in carrying out advanced and trendsetting research in hydrogeochemistry.

## **HEAVY METAL CONCENTRATIONS IN GROUNDWATERS OF CHIKAL THANA AREA OF AURANGABAD, INDIA**

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The Aurangabad urban agglomeration during the last three decades has emerged as a major industrial hub, and one of the fastest developed industrial sectors in India. The heavy industrialization and the increasing urbanization are responsible for the rapidly increasing stress on the groundwater of the area. The enormous quantity of wastewater generated from domestic, commercial, industrial, and other sources, has led to the problems of groundwater in and around Chikalthana Area of Aurangabad. Therefore considering this serious aspect the present study assesses the groundwater contamination due to heavy metals. Groundwater samples were collected in month of May 2009 and analyzed for various water quality parameters.

The analytical data shows very high concentration of total dissolved solids (22.22%), total hardness (57.77%), chloride (22.22%) etc. Heavy metal namely Iron (Fe), Copper (Cu), Zinc (Zn), Chromium



(Cr), Nickel (Ni), Manganese (Mn), Cadmium (Cd), Lead (Pb) were determined by using Atomic Absorption Spectrophotometer (Model Chemito AA 201) as per the standard methods for examination of water and wastewater (APHA, 1995). The analytical data revealed that, groundwater samples are heavily contaminated by Iron, Chromium, Lead and Nickel throughout the area. Urban runoff as well as municipal sewage and industrial effluents could be the main cause of the groundwater contamination spreading by rainwater. A comparison of the results of groundwater with WHO (1993) and BIS (1991) guidelines show that most of the groundwater samples are heavily contaminated with heavy metals. Overall Chikalhana area of Aurangabad is environmental threshold and there is urgent need to reduce groundwater pollution levels before it deteriorates and became unmanageable.

## Keywords

Groundwater quality, Heavy metals, contamination, Aurangabad, India

## HYDROGEOCHEMISTRY OF GROUNDWATER IN BASARA AREA OF ADILABAD DISTRICT, ANDHRA PRADESH, INDIA

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## ABSTRACT

Groundwater is a significant water resource in India for domestic, irrigation and industrial needs. The present study was carried out to assess the groundwater quality in selected villages of Adilabad district, Andhra Pradesh, India, where groundwater is the main source of drinking water. The study area is occupied by pink and grey granites of Archaean age. A total of 34 groundwater samples were collected from hand/bore pumps and analyzed for pH, Electrical conductivity (EC), Total dissolved solids (TDS), Total hardness (TH), Calcium ( $\text{Ca}^{2+}$ ), Magnesium ( $\text{Mg}^{2+}$ ), Sodium ( $\text{Na}^+$ ), Potassium ( $\text{K}^+$ ), Carbonate ( $\text{CO}_3^{2-}$ ), Bicarbonate ( $\text{HCO}_3^-$ ), Chloride ( $\text{Cl}^-$ ), Sulphate ( $\text{SO}_4^{2-}$ ), Nitrate ( $\text{NO}_3^-$ ) and Fluoride ( $\text{F}^-$ ). The results revealed that the mean concentration of cations (in mg/l) is in the order  $\text{Na}^+ > \text{Ca}^{2+} > \text{Mg}^{2+} > \text{K}^+$  while for anions (in mg/l) it is  $\text{Cl}^- > \text{HCO}_3^- > \text{SO}_4^{2-} > \text{NO}_3^- > \text{CO}_3^{2-} > \text{F}^-$ . Fluoride concentration was recorded in the range of 0.06 to 4.33 mg/l. Nearly 41% of groundwater of the study area has more than 1.00 mg/l of fluoride which is the desirable limit and 20% of the groundwater has more than 1.5 mg/l of fluoride which is the permissible limit for drinking purposes. Nitrate concentration was found in the range of 0.4 to 80 mg/l with mean 22.07 mg/l. 20% of the groundwater has more than 45 mg/l of nitrate which is not suitable for drinking purpose. The total dissolved solids (TDS) of the groundwater ranges from 150 to 1355 mg/l in the study area and most of the groundwater falls in freshwater category. The concentration of different ions in the groundwater is shown in the distribution maps.

# **GROUNDWATER POTENTIAL MODELLING IN HARD ROCK TERRAIN THROUGH REMOTE SENSING AND GIS: A CASE STUDY FROM PULIVENDULA- SANIVARIPALLI, KADAPA DISTRICT, ANDHRA PRADESH**

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## **ABSTRACT**

Groundwater constitutes an important source of water supply for various purposes, such as domestic, industrial and agricultural needs. In view of increasing demand of water resources, a greater emphasis is being laid for a planned and optimal development of water resources. Due to the increase in demand of water, there has been an increase in the concentration of earth scientists to find out the highly potential zones of water resources. Similar attempts have been made in the present study and hydrogeomorphological mapping has been carried out for delineation of groundwater potential zones. An integrated survey based on satellite image interpretation corroborated with limited field checks was carried out with a view to assess the natural resources and groundwater potential zones of Pulivendula-Sanivaripalli area, Kadapa district, Andhra Pradesh falling in Survey of India Toposheet No. 57J/03. Remote sensing and Geographic information system (GIS) have emerged as essential tools to meet ever-increasing demand for more precise and timely information. These techniques permit rapid and cost effective natural resources survey and management. Under this study various thematic maps such as geology, geomorphology, drainage, and hydrogeomorphology were prepared, covering an area of about 720 sq km. Based on the hydrogeomorphological mapping the study area has qualitatively been categorized into four groundwater potential zones, viz. good, moderate, poor and very poor. Some of the favourable locations have been suggested to impound the excessive run off so as to augment the ground water resources of the study area.

## **A REVIEW OF RADIONUCLIDE TRANSPORT PARAMETERS OF SOME IMPORTANT HOST ROCKS AND SOILS IN INDIA AND IMPLICATION ON NUCLEAR WASTE DISPOSAL APPROACHES**

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Ability to retard migration of radio nuclides released from the disposed radioactive waste constitutes one of the most important requirements of potential host rocks and soils under consideration for geological disposal of such wastes and thus forms frontier area of applied research in geochemistry.

In India, Low and Intermediate Level Solid Radioactive Wastes are being disposed in Near Surface Disposal Facilities (NSDF) constructed within few meters below the ground surface. Currently seven such facilities are operational in India and are co located with nuclear power plants. Most of these facilities are located in basaltic, sandstones and laterite. Important soil types in these sites include black cotton soil, lateritic soil and alluvium soil. The diffusion coefficient of major isotopes i.e. Cs-137 and Sr-90 in black cotton soils of basaltic terrains are  $5.60 \times 10^{-06} \text{ cm}^2/\text{s}$  and  $1.15 \times 10^{-08} \text{ cm}^2/\text{s}$  respectively indicating better retardation capacity of black cotton soils developed in basaltic terrains. These soils have also yielded Kd values of 600ml/g and 140mg/l for Cs-137 and Sr-90 respectively. In-situ radionuclide transport studies carried out in such soils indicate negligible movement of these radionuclides. Presence of such soils around disposed waste thus does not necessitate application of additional protective layers of suitable clays with high sorption capacity for these radionuclide.

On the contrary, high level waste with long lived isotopes of plutonium, uranium, americium etc are being considered for disposal in deep geological formations with high potential to arrest migration of such isotopes for periods extending over tens of thousands of years. In India, granitic rocks along with suitable clay backfills are under consideration for construction of such disposal facilities. Granites from one such site have shown very high sorption for isotopes of Am, whereas clays show 400ml/g value for Kd in respect of Cs 137. The higher sorption in these granites has been attributed to the presence of minerals like biotite, chlorite, and secondary minerals like sericite, kaolinite and other clays.

## **EXPERIMENTAL STUDIES ON MODIFICATIONS IN SORPTION AND SWELLING PROPERTIES OF HEAT AND RADIATION TREATED BENTONITE CLAYS, NW INDIA**

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### **ABSTRACT**

Bentonite clay deposits of North-West India due to their higher Na-smectite content (54-80%) , large reserves and isotropic compositions are being evaluated for their petro-mineralogy, geochemistry and rock-mechanical characteristics with a view to assess their suitability as buffer and backfill layers in Engineered Barrier System of granite based Deep Geological Repository. The initial estimates indicate requirement of about 110000 tonnes of good quality bentonite clays with relatively uniform smectite content and other desirable characteristics, in the case of Indian geological repository at a depth range of 450-500m with a capacity of 10000 overpacks [1].

Bentonite deposits of this area belong to Akli Formation of Late Tertiary age and are derived from the alteration of acid volcanic and do not show any illitization. These bentonites are characterised by the presence of Na- montmorillonite, kaolinite & quartz as major mineral constituents along with minor amounts of calcite, pyrite, gypsum, organic and ferruginous matter. These deposits are unique in world due to their very high iron content (~8%).

Experimental studies were carried out on these candidate buffer and backfill clays to evaluate loss of their functions when exposed to prolonged heat and radiation emitted by vitrified high-level radioactive wastes in geological repositories. Present paper describes some of the results obtained during the experimental study related to heat & radiation effects. Few selected samples (50 g each) were heat-treated from 50 - 150°C for different time durations (72 – 312 hrs) because maximum temperature envisaged under repository condition is not expected to exceed 150°C [2,3]. Representative swelling clay samples were also subjected to irradiation using <sup>60</sup>Co radioactive source (1173.32, 1332.24 Kev energy) containing 525 kCi of radioactivity and radiation strength of 1.66 k Gray/hr [4,5].

Heat-treated samples were analyzed for their smectite content, swelling volume, CEC and sorption behavior. Experimental studies to investigate the effects of gamma radiation on the properties of swelling clay samples were also performed. Heat-treated samples do not display any significant variations (<10%) in their smectite content. However, noticeable reduction in their swelling volume of the order of ~ 70% has been recorded in some samples treated up to 150°C. The Kd-value tends to increase with temperature and there is almost 40% enhancement in some samples treated up to 150°C. This increase appears to have been accomplished by chlorite and other secondary mineral formation. This needs confirmation. Quite a few samples nevertheless show irregular changes in their Kd-values. This may be attributed to variation in their mineralogy and associated temperature induced transformations. The ability of montmorillonite to rapidly take up water and expand is lost after heating to critical temperature (105-390°C) depending on the amount and type of the exchangeable cations. This appears to be another factor controlling these alterations [6].

Detailed investigations pertaining to mineralogical and morphological alterations in irradiated clay samples were also carried out.

Insignificant alterations were observed in the sample exposed to cumulative dose of 1 × 10<sup>5</sup> Gray. However, significant reduction in the swelling ability of the clay was noticed in case of the sample exposed to integrated dose of 5 × 10<sup>5</sup> Gray. In addition, remarkable increase in sorption potential for <sup>137</sup>Cs (Kd for <sup>137</sup>Cs) was observed. While negligible variation in CEC can be attributed to relatively lower dose of radiation, but there is no plausible explanation to account for the increased Kd for Cs. No detectable variations in morphological features like flake-like structure could be observed in heat-treated as well as irradiated clay samples.

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## **CHEMISTRY AND MINERALOGY OF SOILS AS INFLUENCED BY CLIMATE CHANGE**

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### **EXTENDED ABSTRACT**

Soils over basalts of early Holocene to early Pleistocene ages in Purna valley (20°10' to 21°41' N to 76°0' to 77°55' E) of Central India were investigated to infer pedogenic, mineralogical and geochemical transformations as influenced by climate change. The soils are strongly alkaline with dark reddish brown to dark yellowish brown matrix enriched with iron and calcium carbonate nodules and lithological discontinuities near Wishroli and Brahmanwara villages, cambic horizons in Muchkera, clayey, sodic slickensided horizons near Moregaon and Wadali Sahini and buried gravelly beds over strong brown natric horizons (>40% clay) near Kalashi and Andura villages. The elemental analysis showed that SiO<sub>2</sub> content is 60 to 70 per cent in soils of Wishroli, Brahmanwara and Kalashi but less than 60 per cent in other soils, whereas, the Al<sub>2</sub>O<sub>3</sub>, Fe<sub>2</sub>O<sub>3</sub>, CaO, MgO and Na<sub>2</sub>O contents increases with degree of weathering and clay content. The pedogenesis in these soils are assessed with molar ratios of elemental composition showed that the salinisation, calcification and base enrichment are dominant processes with varying degrees as controlled by fluctuating climate, local topography and drainage conditions. The calcification as expressed through molar ratios yielded strong correlation with rainfall. These soils in general showed gains of SiO<sub>2</sub>, Fe<sub>2</sub>O<sub>3</sub>, MnO and K<sub>2</sub>O and losses of CaO, MgO and Na<sub>2</sub>O.

Micromorphological and XRD studies indicate the occurrence of ferriargillans in Kalashi and Andura soils and the smectites of Moregaon and Wadani Sahini soils respectively which indicated the prevalence of humid phase in the past. Huge amount of well crystallized smectites in these soils must have been formed upon weathering of plagioclase of Deccan basalt in an earlier humid climate and deposited in lower elements of topography where vertisols generally occur in the relatively less leaching environment of the drier climate. Further, preservation of crystallinity in smectites indicates termination of humid phase and the beginning of drier arid phase around 4.5 ka BP (Pal et al., 2001). Abundance of smectite minerals in the clay fraction of palaeosols is also important from the point of view that higher amount of smectites are known for their swell-shrink properties and has the tendency to imparts vertic properties to the soils. However, presence of iron oxides possibly hematite and goethite possibly reduce

the dispersiveness and swell shrink activities of smectites in Alfisols. High amount of exchangeable magnesium in the clay complex may also reduce the structural stability in these soils. The aridity during late Holocene had favoured the formation of pedogenic carbonates (PC) and the concomitant development of sodicity (Pal et al., 2009) in Purna valley during Holocene. The study concludes that the soils in the study area carry imprints of climatic fluctuations from humid to arid phases through modifications in their chemical and mineralogical characteristics.

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## NUCLEAR WASTE DISPOSAL – FROM THE PERSPECTIVE OF A GEOCHEMIST

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### ABSTRACT

Satisfying the growing energy requirement in an environment friendly way is one of the most important tasks we need to accomplish these days. Considering the restricted non-renewable energy resources and limited technological progresses achieved in the renewable energy sectors in India, Nuclear Energy appears to be one of the most lucrative solutions towards the forthcoming energy crisis. Successful implementation of nuclear energy program however requires careful execution of high level nuclear waste management activities. One very important aspect of this process is to identify and develop suitable inert matrix(es) for conditioning of nuclear waste(s) using natural analogue studies. And this establishes the very vital linkage between geochemical studies and nuclear waste immobilization.

One good example of such an interdisciplinary approach can be seen in the methodologies adopted for immobilization of sulfate bearing high level nuclear wastes (SO<sub>4</sub>-HLW). It has been reported on several occasions that sulfur-rich melt get separated from silicate melt within magma chamber. Similar process has also been witnessed within vitrification furnaces whenever an attempt has been made to condition SO<sub>4</sub>-HLW within borosilicate glass matrices. Since such liquid-liquid phase separation leads to multiple difficulties in connection to radionuclide immobilization and plant scale vitrification processes, solutions were sought from natural analogue studies. Such an integrated approach ultimately resulted in establishing two different methodologies e.g. (i) modifying the borosilicate network through introduction of Ba<sup>2+</sup> cation; a process being followed in India and (ii) using phosphatic melt as a host instead of borosilicate melt; a process being followed in Russia. Detail of these two routes and the geochemical linkage in nuclear waste immobilization will be discussed.

# ENVIRONMENTAL GEOCHEMISTRY OF MARINE SEDIMENTS OFF POOMBUHAR, SOUTHEAST COAST OF INDIA.

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## ABSTRACT

Geochemical studies of surface sediments along the coastal zone have been extended in the last few decades due to the growing awareness of coastal pollution and its impact on the ecosystem. The sediments at the sea bottom play an important role in the pollution scheme of a coastal ecosystem, as they are less susceptible to movement than the water column. When the effluent loaded water meets the coastal zone, various physico-chemical reactions take place and a large part of the pollutant, in one form or other, settles down, or is adsorbed by the oceanic sediments depending upon the physico-chemical conditions. In the past few years, there have been numerous instances of man-induced metal contamination to inland and coastal sediments. To study the environmental condition of the marine environment Off Poombuhar, 38 Sediment samples were collected off the coast of Bay of Bengal north of Nagappattinam. The samples were analysed to understand the geochemistry of the marine sediments along the coastal tracts and their pollution rate using various geochemical indices. The sediments collected were analysed for textural analysis, total organic carbon, calcium carbonate, major and trace elements. The indices used for analysing the pollution load are Enrichment Factor, Contamination Factor, Igeo Index and Pollution Load Index. Al is used as a normalizer to calculate the enrichment factors. Based on the enrichment factor Cu, Cr and Zr shows enrichment more than 2. Taking in to account the level of the average contamination factor (CF) values, Zr, Cr, Cu and Th are found to be higher (>1). The Geoaccumulation index (Igeo) based on shale values (Wedepohl, 1995) showed values less than one for all the trace metals except Zr, Cu and Cr and in which Cu showed higher value (9). Considering the Pollution Load Index (PLI), the PLI value is <1 in the study area. The study reveals most of the elements are lithogenic in origin, except Cu, Cr and Zn which are of anthropogenic in nature. As the area is pristine and no polluting industries near by, the enrichment of the above said elements might have been received from the upper reaches of River Cauvery.

# **EFFECTIVE TREATMENT TECHNOLOGIES OF EFFLUENTS – A CASE STUDY FROM INDUSTRIAL BELT, HYDERABAD, INDIA**

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## **ABSTRACT**

Effective and low cost treatment methodologies are one of the major concerns to the environmental scientists. The effluents released from industries are to be effectively treated before their release into public drains. In this paper, the adsorbent treatment technologies using Fly ash, Activated carbon and saw dust are tested for their effectiveness. The wastewaters from different industries like textile, tanning, chemical industries and electroplating and drug formulations are considered for the treatment. The water samples of waste water, water treated in the respective treatment plants of the industries and the water treated through the treatment methodologies developed for this study are analyzed for various chemical constituents present. The chemical analysis data statistically compared to identify the performance of each treatment technology and its cost-effective application for each type of the industry. The statistical parameters considered here are the arithmetic average, standard deviation, standard error of the mean and variance in addition to the normalized graphs for each treatment. The data was also subjected to t-test to know the significant difference between the raw sample data and the sample taken from each industry. From this it can be inferred that if the difference is not significant we may conclude that the treatment methodology may be ineffective for that physico-chemical parameter. In other words if the treatment methodology is effective we expect a large difference in the raw sample and the treated sample, and it will be reflected as a significant difference in the t-test. For most of the samples the differences are clear even for visual observations. From the t-test it is observed that the treatment methodology is not that effective for dissolved oxygen, dissolved silica and phosphates. The normalized graphs show the effectiveness of each treatment methodology.

## **ENDOSULFAN CONSPIRACY IS A “GLOBAL PROBLEM” BIRD’S EYE VIEW**

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## **ABSTRACT**

Endosulfan is a toxic pest killer, its poisoning is a “global problem” and comparable to “Bhopal disaster”. Endosulfan is an organo chlorine pesticide called “organochlorines”. These chemicals are classified among the worst of pops {persistent organic pollutants}.

The health impacts by the use of Nitrogenous fertilizers are know viz. “Blue baby syndrome” or “methamaglobinamial” disease and for heavy smokers the hemoglobin is called”Carboxyhemoglobin”.



Similarly the health impacts due to utility of endosulfan are known viz. neurotoxic, muscular contraction, convulsions, loss of consciousness, dizziness, diarrhoea, breathing difficulties, memory loss, liver cancer, cardiovascular disorders, gynecological disorders and birth defects etc., Kerala's Kesargod district among the world's worst endosulfan hit regions.

Today endosulfan is banned in U.S.A., U.K., Germany, Brazil, Canada, Pakistan, West Africa. There is a proposal to Government of India to ban endosulfan by Govt. of Karnataka, to ban endosulfan in Karnataka because of ill-health effects in parts of South Kanara, North Kanara districts of Karnataka. Because of no scientific and epidemiological studies were carried out neither in the country nor in southern states like Kerala, Karnataka Govt. is considering to ban it. No side effects were noticed in West Bengal, Punjab and Orissa states. The details will be discussed.

## **HOT SPOTS OF LEAD POLLUTION AND IMPACTS ON THE BIO-SYSTEMS**

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### **ABSTRACT**

Lead is a naturally occurring bright bluish white, highly poisonous and dangerous element. The lead, zinc and copper deposits are located in India in peninsular Indian shield and smaller extent in lesser Himalayan belt. Lead enters into the environment due to exhaust of heavy vehicle movement, various anthropogenic and also due to mining activities. Lead is lithophile, atmophile, hydrophile, biophile and chalcophile element causes various environmental problems and bizarre health and hygiene problems.

Lead is nephrotoxic, neurotoxic, psychotoxic element, causing bizarre health hazards like low I.Q., neurological complications, headache, anemia, kidney failure. Cancer, Asthmatic problems. Radioactively generated lead causes a disease called “motor neuron” disease. Mining of copper, lead, zinc, manganese ores and inhalation of these ore dust causes a disease called “alzhimers” disease. Small amounts of lead in the body cause learning problems and changes in behavioural attitude. Lead is toxic to sperms and significantly in men and cause oligospermia, asthenozoospermia, teratozoospermia and reduce vitality and abnormal HOS scores. Lead pollution also causes hypertension, hyper activity. Hyperirritability and lead in the human body is fatal. The children's IQ is directly linked to lead pollution levels in the atmosphere. The lead pollution in atmosphere hampers mental growth of pregnant women in the urban sprawls.

The available lead values are as follows: The marine fish canacona, Goa analyses lead upto 8 ppm (Kariyanna, 2004), the salsette esturine sediments upto 27.2 mg/L (Sahoo, et al., 1987), Ulhal esturine organisms, Mumbai upto 32 mg/L (Srinivasan, et al., 1987), the zuari esturine sediments Goa upto 24 ppm (Kariyanna, 2009) and Mandovi esturine sediments, Goa upto 54.70 ppm (Karayanna, 2009).

Certain known bioremediation techniques to minimise lead pollution problems (Kariyanna, 2008) include: the Indian mustard plant can extract heavy metals like lead and chromium and the sunflower has shown concentration of uranium in the roots. In Mamandur multi metal prospect, Tamilnadu, the plant waltharia indica thrives the zone of mineralization (Murthy, N.G.K., 1964). Impetus bolsamina has noticed on lead zinc deposits of zavar (Poddar, 1965), polycarpea spyrostylis and P. corymbosa in Agnigundala multi metal prospect (Venkatesh, 1964 and Roy Choudary et al., 1969). Erianthus giganteus absorbs lead in Tennessee, Baptisia bractanta absorbs lead in Wisconsin, Alyssumwalfemianum is a lead universal geobotanical guide in Australia and Italy. Calicarpa argorea is geobotanical guide for Cu, Pb, Zn deposits in Meghalaya.

The nephrotoxic elements like lead, mercury and cadmium could cause severe kidney failure problems due to their pollution pattern in the environment and their environmental geochemistry has not clearly understood world over. An indepth study is required in coordinated approach of environmental scientists, nephrologists, neurologists etc.

## **GEOCHEMISTRY OF GROUNDWATER IN AND AROUND MAGAMPETA BARITE DEPOSIT, CUDDAPAH DISTRICT, ANDHRA PRADESH, INDIA**

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### **ABSTRACT**

Hydrogeochemical study was undertaken to assess the quality of groundwater and it's suitability for domestic and irrigation purposes in and around Mangampeta Barite mining area, covering the Obulavaripally mandal of Cuddapah district of Andhra Pradesh. The rock formations of the study area belong to Cuddapah supergroup and the important litho-units consist chiefly of quartzites, limestones and shales. Mangampeta barite deposit occurs in the Pullampeta formation of Cuddapah system. The barite deposit is inter layered with thick bands of grey and black shales. Fifty groundwater samples were collected from the bore wells and hand pumps covering the entire study area. The quality analysis is made through the estimation of various parameters viz., TDS, TH,  $\text{Ca}^{++}$ ,  $\text{Mg}^{++}$ ,  $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{CO}_3^{-2}$ ,  $\text{HCO}_3^-$ ,  $\text{Cl}^-$ ,  $\text{SO}_4^{-}$ ,  $\text{NO}_3^-$  and  $\text{F}^-$  in addition to pH, and Ec. In the study area pH ranges from 6.85 to 9.7,  $\text{Ca}^{++}$  ranges from 18 to 381 mg/l,  $\text{K}^+$  2 to 80 mg/l,  $\text{Na}^+$  12 to 68 mg/l,  $\text{CO}_3^{-2}$  0 to 30 mg/l,  $\text{HCO}_3^-$  260 to 817 mg/l,  $\text{Cl}^-$  53 to 475 mg/l,  $\text{SO}_4^{-}$  4 to 100 mg/l,  $\text{F}^-$  0.19 to 0.58 mg/l, TH 105 to 505 mg/l. The data has been processed with various graphical methods for characterization of groundwater and distribution maps for each element have been prepared. It is found the water quality is suitable for both domestic and irrigation purposes.

# **GEOCHEMISTRY OF GROUNDWATER IN KALWAKURTHY AREA, MAHABUBNAGAR DISTRICT OF ANDHRA PRADESH WITH SPECIAL REFERENCE TO FLUORIDE DISTRIBUTION**

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## **ABSTRACT**

Hydrogeochemical investigations were carried out in Kalwakurthy region of Mahabubnagar District, Andhra Pradesh, covering 290 sq km area. The study area is occupied by grey and pink granites of Archaean age. Fifty six representative groundwater samples were collected and analyzed for pH, EC, Ca<sup>++</sup>, Mg<sup>++</sup>, Na<sup>+</sup>, K<sup>+</sup>, CO<sub>3</sub><sup>-2</sup>, HCO<sub>3</sub><sup>-</sup>, Cl<sup>-</sup>, TH, TDS, SO<sub>4</sub><sup>-</sup>, NO<sub>3</sub><sup>-</sup> and F<sup>-</sup>. The results showed that the concentrations of Fluoride and Nitrate in groundwater are more than the permissible limits prescribed for drinking purposes in some areas. The nitrate concentration in groundwater is varying from 1.1 to 112.5 mg/l. The studies revealed that nearly 40% of groundwater has more than 45 mg/l of nitrate which is the desirable limit. It is observed that the nitrate concentration is more in the Kalwakurthy area. The fluoride concentration in groundwater is varying from 0.36 to 2.56 mg/l. The fluoride concentration is exceeding the desirable limit of 1.0 mg/l in 44% of groundwater. In 35% of groundwater the fluoride concentration is exceeding 1.5 mg/l which is the permissible limit. The data has been processed with various graphical methods for characterization of groundwater and distribution maps for each element have been prepared.

# **GEOCHEMISTRY OF GROUNDWATER IN DEVARAKONDA AREA, NALGONDA DISTRICT, ANDHRA PRADESH, INDIA**

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## **ABSTRACT**

Hydrogeochemical investigations were carried out in the Devarakonda area of Nalgonda District of Andhra Pradesh. Sixty groundwater samples were collected from both bore wells and dug wells to monitor the Hydrogeochemistry of various ions. The area is occupied by granites of Archaean age. The present study was undertaken to understand the geochemical behavior of various ions in groundwater viz., TDS, TH,  $\text{Ca}^{++}$ ,  $\text{Mg}^{++}$ ,  $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{CO}_3^{2-}$ ,  $\text{HCO}_3^-$ ,  $\text{Cl}^-$ ,  $\text{SO}_4^{2-}$ ,  $\text{NO}_3^-$  and  $\text{F}^-$  in addition to pH, and Ec. The nitrate concentration in groundwater is varying from 3.1 to 125.5 mg/l. The studies revealed that nearly 50% of groundwater has more than 45 mg /l of nitrate which is the desirable limit. It is observed that the nitrate concentration is more in the Devarakonda township area. The fluoride concentration in groundwater is varying from 0.5 to 2.86 mg/l. The fluoride concentration is exceeding the desirable limit of 1.0 mg/l in 38% of groundwater. In 20% of groundwater fluoride concentration is exceeding 1.5 mg/l which is the permissible limit. The data has been processed with various graphical methods for characterization of groundwater and distribution maps for each element have been prepared.

**ANALYTICAL TECHNIQUES  
AND DATA PROCESSING**

# **ROLE OF ANALYTICAL CHEMISTRY IN GEOCHEMICAL APPLICATIONS**

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With the passage of time analytical chemistry has gone on from strength to strength, mainly due to the miniaturisation of instruments and improvement in the sensitivity of the detector systems. The analytical data produced instrumentally are far more dependable than what it was a decade back. Improved digitalisation, increased sensitivity of detection methods, leading to much improved estimations, improved accuracy of determinations, etc, are all responsible for the above. In geochemical studies, high sensitivity and accurate determinations are two key words, very much needed for useful exploration of geological samples. However, the operators of such instruments, be they the technicians or scientists, consider such instruments as mere black boxes. This tendency is suicidal and must be avoided at all costs. For each determination method, the analyst should start from the first principles and end at a detailed familiarisation of the components of an instrument. The analysis part then becomes a routine affair. It is also important to know the intricacies involved in the sampling techniques and the statistical presentation of the analytical data.

An overview of all these will be presented in the present lecture.

## **EFFECT OF GRAIN SIZE ON WDXRF ANALYSIS OF CHLORITE-BIOTITE-SCHIST SAMPLE FROM NARWAPAHAR, SINGHBHUM DISTRICT, JHARKHAND, INDIA**

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### **ABSTRACT**

Elemental analysis of geological materials like rocks, minerals and ores using Wavelength Dispersive X-ray Fluorescence (WDXRF) Spectrometry is regarded as one of the most important and popular techniques in geochemical exploration. It gives fast, precise and accurate analysis of geological materials across a wide range of elements (Na-U), from trace amounts (ppm) to percentage level. WDXRF analysis is advantageous in respect of essentially hazard-free sample preparation with no time-consuming chemical methods.

Major, minor and selected trace elements analysis on Chlorite-biotite-schist samples from Narwapahar, Singhbham district, Jharkhand, was carried out using WDXRF Spectrometer (PW-2440; Magi XPRO). The fluorescence intensity varies depending on grain size and heterogeneity of the sample. Minerals such as mica, chlorite may align preferably parallel to the pellets surface during compression and presence of different accessory minerals also poses problems. To minimize this problem, the samples must be ground as much fine as possible. Powder pelletisation sample preparation technique has been

adapted for the present study. The samples were weighed (1g) and manually sprinkled over a boric acid bed (20g) which has been used as a backing material and subsequently the pellets were made within a sample dia(41mm diameter) using a semi automatic hydraulic press at a pressure of 20,000 kg/cm<sup>2</sup>. The samples ground to four different grain size fractions: <38 µm (-400#), 38-44 µm (+400 to -325#), 44-75 µm (+325 to -200#), and 75-106 µm (+200 to -150#) use ASTM Sieves. The results indicated that coarser fractions estimated more SiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub> and Na<sub>2</sub>O indicating the layering effect and also analysed very high total (104%). The finer fractions analysed close to 100 % total indicating effect of grain size on the samples. The results indicate that concentration of some of the trace elements increases as the grain size decrease from 106 µm to 38 µm, Viz., Cr:71-107ppm, Ni:147-166ppm, Cu:97-135ppm, Pb:42-54ppm and U:191-236ppm. The observation substantiates that minor accessory ore minerals get liberated at fine size and the sample becomes more homogeneous. This paper discusses the grain size effect on WDXRFS analysis of Chlorite-biotite-schist samples from Narwapahar, Singhbhum district, Jharkand and suggests that the optimum grain size is <38 µm ideal for precise analysis.

## **DETERMINATION OF ARSENIC, ANTIMONY, BISMUTH, SELENIUM AND TELLURIUM IN THREE IN-HOUSE GEOCHEMICAL REFERENCE MATERIALS BY FLOW INJECTION OR CONTINUOUS FLOW-HYDRIDE GENERATION-ATOMIC ABSORPTION SPECTROMETRY**

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### **ABSTRACT**

Trace amounts (from nanogram to microgram levels) of arsenic, antimony, bismuth, selenium and tellurium were determined by hydride generation atomic absorption spectrometry in three in-house geochemical reference materials issued by the Geological Survey of India. The hydride generation technique was used to separate arsenic, antimony, bismuth, selenium and tellurium from samples analyzed in the form of powder. The accuracy and precision of the experimental values were assessed by the comparative analysis of well established reference materials such as IGGE, GSD-2, GSD-3, GSD-4, GSD-5, GSD-6, GSD-10 and GSS-8. The measured values (for reference materials) agreed well with the reported values within a 10% error range.

Reliable new data for these elements in the three geochemical reference materials, PKS-1 (Palakkad Kerala Soil-1), PKSS-1 (Palakkad Kerala Stream Sediment-1), AASS-2 (Anantpur Andhra Pradesh Stream Sediment -2) prepared by Geological Survey of India have been reported for the first time. The indicative values in µg/g for PKS-1 are; arsenic 2.31±0.30, antimony 0.18±0.03, bismuth 0.074±0.017, selenium 1.05±0.15 and tellurium 0.059±0.007 & for PKSS-1 are; arsenic 1.21±0.20, antimony 0.09±0.02, bismuth 0.03±0.01, selenium 0.41±0.07 and tellurium 0.025±0.004 and for AASS-2 are; arsenic 1.18±0.20, antimony 0.09±0.02, bismuth 0.05±0.01, selenium 0.06±0.01 and tellurium 0.012±0.002. These in-house reference materials are intended to be used mainly for NGCM program for 1) The calibration of an apparatus/instrument, 2) the development and assessment of a measurement technique, and 3) to control and assure the quality of data generated sans any inter-laboratory and interpersonal bias.

# A SIMPLE ECONOMIC AND QUANTITATIVE METHOD FOR THE REMOVAL OF URANIUM FROM GOGI MINE WATER USING POWDERED RED BRICK

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## ABSTRACT

A simple and economical method for the removal of uranium from Gogi mine water using the powdered red brick as a good adsorbent is discussed.

Structurally affected Meso-neoproterozoic Bhima sediments as well as underlying Neoproterozoic Paleoproterozoic basement granitoids host the medium grade (0.17%  $U_3O_8$ , average grade) uranium deposit in Gogi area, Yalgiri district Karnataka. The ore body is located in a marshy land in the vicinity of two natural lakes viz. the “Gogi Lake” in the north and the “Rabanahalli Lake” in the west. Major portion of the ore body is in constant contact of the ground water within the marsh land due to the shallow water table (<5m level). The natural ground water gradient in the region is in the north and north east direction. Therefore the mine development and excavation possibly affect the ground water and there is a chance of contaminated water likely to enter the public domain.

In order to monitor the variations in ground water chemistry, water samples from eight different locations including the exploratory mine were, periodically analysed. These locations were selected to represent the areas surrounding the mine at distances from 100m to 700m. The uranium data obtained by analyzing these samples collected during the period Jan.2010 to Dec.2010 showed the variation of uranium values from 15 mg/L to 2000 mg/L. This may be due to the mixing of mine effluent with these water bodies. Water from some of these locations was used for agricultural and domestic purposes. The WHO guide lines fixed the maximum uranium concentration in drinking waters to be less than 20 mg/L<sup>1</sup>. Daily intake of uranium and its compounds cause progressive or irreversible renal injury. For this reason removal of uranium from mine water is of great importance. Several methods such as chemical precipitation, solvent extraction, reverse osmosis, organic and inorganic ion-exchange and adsorption process have been described for the removal of uranium from aqueous solutions<sup>2</sup>. Several organic and inorganic adsorbents<sup>3, 4</sup>, living and non living biomass<sup>5</sup> has been investigated as adsorbents for the removal of uranium from water and waste water.

Uranium removal using ferric hydroxide co-precipitation<sup>6</sup> is a well known procedure and it has been successfully standardised for Gogi Mine waters<sup>7</sup>. However, this method requires the pH adjustment which in turn renders the water unsuitable for domestic purposes. Hence removal uranium from mine water by selective adsorption of uranium on powdered red brick which is locally available is explored.

Preliminary studies for the removal of uranium using brick showed encouraging results. Further studies were carried to find the amount and size of brick for the quantitative removal of uranium. The results of these studies showed that 50 g of brick with #10mesh size was enough to remove uranium quantitatively from 100 ml of mine water containing 1800  $\mu\text{g/L}$  of uranium. However the column studies indicated considerable decrease (~5 g for 100ml of mine water) in the amount of brick required to remove uranium from 100 ml of mine water.



Studies were carried out to find the effect of pH on the adsorption of uranium from mine water using brick. The results showed more than 98 % adsorption in the pH range 6-9. The above studies indicate the removal of uranium from mine water using powdered red brick can be achieved with out any adjustment of the pH (pH of the mine effluent varied from 7.5-9).

Experiments carried out to find the breakthrough volume of mine water for the removal of uranium using brick showed 200 ml of 1800  $\mu\text{g/L}$  of uranium as the breakthrough volume of mine water for 20 g of brick. The breakthrough volume of mine water for 20g of brick is the volume of mine water which after passing through brick gives uranium concentration below 10  $\mu\text{g/L}$ . Hence the adsorption capacity based on these values of brick for uranium is 18  $\mu\text{g/g}$ .

Similar experiments carried out using iron oxide coated sand also gave promising results. But the addition of iron oxide coated sand to the mine water showed some change in the pH and conductivity and also an increase in the iron content of water. But iron oxide coated sand showed a better adsorption capacity for uranium compared to brick. However brick was selected in preference to iron oxide coated sand for the removal of uranium from mine water as it is easily available and no further pre-treatment is required for the water.

#### Procedure for the removal of uranium from mine water using brick

Around 5g of brick was packed in a glass column of 12mm diameter with a column height of 15 cm length, 100 ml of Gogi mine water was passed at the rate of 1ml/minute. Known volume of the solution after passing through column was analysed for its uranium content using Laser induced fluorimeter-Scintrex UA-3 analyser. The results obtained are given in Table-1.

**Table. 1** Removal of uranium from mine water using powdered red brick

Sl. No	Uranium concentration in water before adsorption ( $\mu\text{g/L}$ )	Uranium concentration in water after adsorption ( $\mu\text{g/L}$ )	% Adsorption
1	1818	10	99.5
2	2130	12	99.4
3	970	6	99.4
4	720	6	99.4
5	1360	12	99.2

## Conclusion

The use of powdered red brick as an adsorbent for uranium from Gogi mine water is a simple, quantitative and economical method for uranium removal. Added advantage of this procedure over the existing methods is that no chemical is added into the water during the treatment leaving the quality of the water unaltered.

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## **A SIMPLE, RAPID AND DIRECT DETERMINATION OF SILVER IN GEOLOGICAL SAMPLES BY GRAPHITE FURNACE ATOMIC ABSORPTION SPECTROPHOTOMETER**

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### **ABSTRACT**

Silver is an element of economical importance. It occurs in small amounts in pyrites and other sulphide minerals. Crustal abundance of silver<sup>1</sup> is 60 ng/g, therefore accurate determination is very difficult. Graphite furnace AAS determination of silver is an excellent determination technique for silver due to its very high detection power (DL 5 pg). Therefore, attempt is made to systematically assess the suitability of the technique for direct determination of silver<sup>2</sup> in certain types of geological materials like granite, quartzite and dolomite after their complete sample decomposition using a mixture of nitric acid and hydrofluoric acid. Sample solution is prepared in 3% nitric acid and 16 µL of the sample solution is injected into the furnace along with 4 µL of 0.5 % (w/v) ammonium dihydrogen phosphate (ADP) as matrix modifier. Calibration is carried out between 16-96 pg of Ag.

### **Instrumentation**

An Atomic Absorption Spectrophotometer GBC Avanta P equipped with graphite furnace GF 3000 and an auto sampler is used. Deuterium background correction system is employed and argon is used as inert gas. Sample solution is injected into pyrolytic graphite tubes.

### **Optimisation of Ash/atomization Temperatures**

As the ash temperature is increased from 500°C to 800°C in the absence of matrix modifier, it was observed that beyond 600°C, the net absorbance of Ag decreased indicating the premature volatilization of silver. In the presence of modifier up to 800°C, no significant change in the absorbance was observed. It was observed that as atomization temperature is increased from 1800°C to 2600°C, absorbance decreased gradually. Maximum absorbance was obtained when the atomization temperature was in the range of 1800°C to 2000°C<sup>3</sup>.

## Matrix Modifiers

Though modifiers like nickel, ascorbic acid, thiourea, lanthanum, ADP and palladium were studied, ADP<sup>4</sup> is found to be the best when rock sample solution is directly injected in the graphite tube. The amount of ADP was varied from 20 to 80 µg in presence of 48 pg of silver, no significant change in the absorbance signal was noticed. Therefore 20µg of ADP was fixed for further studies.

## Effect of Major Matrix Elements like Fe, Al, Ca & Mg on Silver Absorbance

It was observed that the presence of 32 µg of Fe do not affect the absorbance signal of 48 pg of Ag. But calcium and magnesium depress the absorbance signal<sup>4</sup>. Under the same conditions aluminum enhances the absorbance signal. However, these effects are considerably reduced in presence of 20 µg of ADP. Studies carried out with graphite tubes with integrated platform did not yield encouraging results under the above conditions. Some other transition metals like Cu, Ni, Co, Pb, Zn, Mo, V, Cr at a concentration of 10µg/ml in rock sample solutions do not affect the signal of silver when 16 µL is injected into the graphite furnace.

## Application to Geological samples like Granite, Quartzite and Dolomite

Sample solutions of these materials were prepared as mentioned. The silver analysis was carried out by the proposed method for the direct determination by GFAAS and also by conventional tellurium co-precipitation separation<sup>5</sup> of silver using 10 g sample followed by Flame AAS determination. The results obtained are given in Table 1 along with the values obtained for some international reference materials supplied by CANMET like Iron ore FER-1, Sudbury concentrate PTC-1a, Ni- Cu- Co ore Su 1a. The results agreed well, indicating the accuracy of the method. The RSD obtained was well within 5 %.

## Conclusion

The direct determination of silver by GF- AAS employing ADP as modifier at an ash/atomization temperature of 700/1900°C, facilitates a simple and rapid estimation of silver at very low level accurately. The method is applied on geological samples of different nature like granite, quartzite and dolomite.

**Table. 1.** Analytical results of some international reference materials for silver and granite, quartzite and dolomite samples (all values in µg/g)

Nature of sample	Conventional method <sup>5</sup>	Present method
CANMET- Iron ore FER 1	5.3*	4.9
CANMET- PTC-1a	56*	54.7
CANMET Ni- Cu- Co Ore -Su 1a	4.30*	4.10
Granite 1	7.25	6.70
Granite 2	5.40	5.10
Quartzite 1	4.66	4.34
Quartzite 2	1.91	1.87
Dolomite 1	2.56	2.28
Dolomite 2	2.50	2.40

\*Recommended values

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## ICP-MS DETERMINATION OF RARE-EARTH ELEMENTS AND THORIUM IN URANIUM-RICH GEOLOGICAL SAMPLES

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### ABSTRACT

Uranium is the key fuel element in the field of nuclear energy. Hence, it often becomes necessary to determine trace constituents especially the rare-earth elements which are important geochemical tracers and also occur as radio-nuclides in the decay series of nuclear fission, in a variety of uranium-rich samples like uranium concentrates and reactor fuel grade samples as well as environmental and geological samples. Analysis of trace constituents in uranium-rich samples poses a challenge to the analysts. Among the gamut of analytical techniques available, solution ICP-MS has emerged as a powerful and sensitive technique that has been successfully applied for the accurate direct determination of trace elements in geological materials, as it offers rapid analysis capability, ability to measure most elements in the periodic table, low detection limits and a large linear dynamic range. But, it suffers from mass spectral interferences arising from isobars, doubly charged and polyatomic species and also from very low tolerance to total dissolved salts [TDS]. Apart from spectroscopic interferences, non-spectroscopic interferences arising from difference in behavior of sample solutions also occur. Differences in acidities and TDS significantly affect accuracy and precision. Matrix effects known as space charge effects also occur during excitation in the plasma. In ICP-MS, a large excess of a single element can cause enhancement or suppression of analyte signals, especially those of the lighter mass elements. These space charge effects are extreme when heavy mass elements like uranium are present at high concentrations and may also occur due to light mass elements like sodium. The effect of concomitant elements in ICP-MS has been studied at a single set of operating conditions by some workers. It has

been reported that some concomitant elements (Na, K, Cs, Mg, Ca) induce an enhancement of the analyte signals while another (Li) does not have any significant effect and others (B, Al, U) cause a suppression. In view of the above, even with ICP-MS, direct determination of trace constituents in uranium-rich geological materials could be extremely difficult because of the high levels of TDS and space charge effects arising from the heavy uranium matrices. Therefore, in the present work, the extent of signal suppression on all rare-earth elements and yttrium due to the uranium matrix has been studied at a single set of operating conditions for different amounts of uranium taken and the tolerance limits have been evaluated. A platform-XS model ICP-MS from Micromass Limited, U.K was used for the measurements. The instrumental parameters and operating conditions are given in table 1. Solutions containing 0.05g/100mL of certified reference materials (CCRMP's SY-2) doped with and 1-500 µg/mL of uranium were prepared, and rare-earths, yttrium and thorium were determined by ICP-MS and the recoveries calculated in the presence of the uranium matrix. The results obtained are given in table 2. Significant space charge effects on the rare-earth elements and yttrium were observed. Uranium concentrations of 100 µg/mL caused significant signal suppression leading to error of about 7.4% to 12.5% in the values obtained [table 2] whereas uranium concentrations of 500µg/mL caused errors as high as 20% in the case of most REE's. Some selected uranium-rich samples and two uraninite samples were analysed by ICP-MS to estimate the extent of error arising from space charge effect of the uranium matrix in real samples. Solutions of three uranium rich samples (containing 5-10% uranium) originating from different field areas were prepared using HF-HNO<sub>3</sub> decomposition method and rare-earths and thorium were determined by ICP-MS in presence of the uranium matrix as well as after solid phase extraction separation of the uranium matrix using activated carbon as sorbent in fluoride medium and results obtained are given in table 3. The values were in good agreement since the uranium levels in the sample solutions aspirated into the plasma were kept below 50µg/mL by applying appropriate dilution. Hence, it was concluded for samples containing upto 10% uranium matrix separation is not essential and direct determination of trace constituents is feasible with good accuracy and precision as appropriate dilution would keep the uranium levels well within the tolerance limits. Sample solutions of two uraninite mineral samples were also prepared. Since, the amount of uranium present in these samples was very high (50-60 % U), the above sample solutions could be analysed by ICP-MS only after removal of the major uranium matrix by employing a solid phase extraction step using activated carbon as sorbent in fluoride medium and the results obtained are given in table 4. The values obtained by ICP-MS were in good agreement with those reported using ICP-OES. Hence, it was concluded that for trace element analysis of highly uranium-rich samples like uraninite or cake samples, uranium separation is essential to ensure good accuracy and precision of the results obtained by ICP-MS.

**Table 1: Instrumental parameters & Operating conditions of ICP-MS**

<b>Analyser</b>	
Cone lens voltage	- 390V
Hexapole Exit Lens voltage	- 380V
Hexapole bias	0.0V
<b>Detector</b>	
Photo multiplier voltage	450 V
<b>Pressures</b>	
Analyser vacuum	10 <sup>-5</sup> mbar
<b>Torch</b>	
Forward Power	1250 W
<b>Gas</b>	
Plasma-Cool gas	13.5 L/min
Plasma-Intermediate gas	1.25L/min
Plasma-Nebuliser gas	0.9L/min
Hexapole gas- Helium	8.0 mL/min
Hexapole gas -Hydrogen	4.0 mL/min
Solution uptake rate(pumped)	1mL/min
Spray chamber temperature	3-4°C
Sampler cone	Ni-Cu, 1.1mm orifice diameter
Skimmer cone	Ni, 0.7 mm orifice diameter
Acquisition mode	Peak hopping (SIR)
Dwell time	200 ms

**Table. 2:** Studies on Signal suppression (space charge effects) due to uranium matrix CCRMP-SRM : SY-2 : 0.05g/100mL spiked with known amounts of Uranium

Element Isotope	Actual Value** (ppb) <sup>ss</sup>	Uranium added =5 µg/mL		Uranium added =10µg/mL		Uranium added =100µg/mL		Uranium added =200µg/mL		Uranium added =500µg/mL	
		Analysed Value Obtained (ppb)	% Error	Analysed Value Obtained (ppb)	% Error	Analysed Value Obtained (ppb)	% Error	Analysed Value Obtained (ppb)	% Error	Analysed Value Obtained (ppb)	% Error
89Y	64.0	62.7	3.0	61.2	4.4	59	8.0	54.8	14.3	49.5	22.7
139La	37.5	36.3	3.2	36.1	3.7	33.9	10	32.5	13.4	29.3	22.0
140Ce	87.5	85.4	2.4	85.3	2.5	80	8.6	74.5	14.9	66.3	24.2
141Pr	9.4	9.2	2.1	9.1	3.2	8.5	9.6	7.9	16	6.8	27.7
144Nd	36.5	36.3	1.0	35.5	3.0	33	9.5	31.5	13.7	28.5	21.9
152Sm	8.05	8.0	1.0	7.8	3.1	7.3	10.0	7.2	10.7	6.5	19.3
151Eu	1.2	1.2	<1.0	1.15	4.2	1.05	12.5	1.0	16.7	0.75	37.5
158Gd	8.5	8.3	2.4	8.1	4.7	7.8	8.2	7.5	11.8	6.8	20.0
159Tb	1.25	1.25	<1.0	1.2	4.0	1.1	12.0	1.0	20.0	1.0	20.0
162Dy	9.0	8.9	1.1	8.6	4.4	8.0	11.1	8.0	11.1	7.3	18.9
165Ho	1.9	1.9	<1.0	1.85	2.6	1.65	13.1	1.6	15.8	1.5	21.0
166Er	6.2	6.1	1.6	5.9	4.8	5.5	11.3	5.2	16.1	5.0	19.4
169Tm	1.05	1.05	<1.0	1.0	4.8	0.95	9.0	0.9	14.2	0.75	28.6
172Yb	8.65	8.6	<1.0	8.5	1.7	8.0	7.5	7.8	9.8	7.3	10.4
175Lu	1.35	1.35	<1.0	1.3	3.7	1.25	7.4	1.25	7.4	1.2	11.1
232Th	189.5	187	1.3	185.9	1.0	173	8.7	161	15.0	143	24.5

\*\* Certified values of SY-2 in µg/g[Ref. Geo-Standards NewsLetter, Special Issue,18(1994),p.3] are: Y-128,La-75,Ce-175,Pr-18.8,Nd-73,Sm-16.1,Eu-2.4,Gd-17,Tb-2.5,Dy-18,Ho-3.8,Er-12.4,Tm-2.1,Yb-17.3,Lu-2.7. \$\$ ppb=nanogram/mL

**Table 3 :** Determination of Rare-earths and Thorium in Uranium-rich Geological Samples

Element Isotope	Lab. Sample No.AMD-U1		Lab. Sample No.AMD-U2		Lab. Sample No.AMD-U3	
	Values obtained by ICP-MS without uranium separation ( $\mu\text{g/g}$ )	Values by ICP-MS after separation of uranium ( $\mu\text{g/g}$ )	Values obtained by ICP-MS without uranium separation ( $\mu\text{g/g}$ )	Values by ICP-MS after separation of uranium ( $\mu\text{g/g}$ )	Values obtained by ICP-MS without uranium separation ( $\mu\text{g/g}$ )	Values by ICP-MS after separation of uranium ( $\mu\text{g/g}$ )
89Y	360	355	452	465	297	308
139La	239	220	22	25	17	23
140Ce	608	570	186	192	103	125
141Pr	80	68	44	34	36	21
144Nd	335	325	190	188	163	173
152Sm	112	110	65	68	60	73
151Eu	19	17	14	14	11	10.8
158Gd	93	90	60	68	63	55
159Tb	10.5	11	14	12	11	8
162Dy	90	85	83	79	70	66
165Ho	14	14	14	13	13	9.8
166Er	25	24	39	38	43	30
169Tm	3.8	4.0	6.0	6.3	6.5	6
172Yb	34	35	41	37	33	34
175Lu	3.0	2.5	4.6	4.8	4.6	4.2
232Th	100	103	14	19	17	14

Note:  $\text{U}_3\text{O}_8$  content of samples are: AMD-U1= 1.8%; AMD-U2= 5.9%; AMD-U3= 3.9%

**Table 4:** Determination of Rare-earths and yttrium in Uraninite samples

Element Isotope	Lab. Sample No. AMD-U5		Lab. Sample No.AMD-U6	
	Values obtained by ICP-MS after uranium separation ( $\mu\text{g/mL}$ )	Values reported by ICP-AES after uranium separation ( $\mu\text{g/mL}$ )	Values obtained by ICP-MS after uranium separation ( $\mu\text{g/mL}$ )	Values reported by ICP-AES after uranium separation ( $\mu\text{g/mL}$ )
89Y	1225	1208	1340	1340
139La	31	34	65	57
140Ce	423	394	380	355
141Pr	60	65	51	58
144Nd	420	399	350	372
152Sm	290	270	240	250
151Eu	4	4	65	75
158Gd	230	220	305	340
159Tb	22	25	40	50
162Dy	430	400	305	315
165Ho	31	38	50	51
166Er	65	60	115	123
169Tm	6	5.5	15	15.3
172Yb	45	50	94	110
175Lu	6.8	8.5	13	14

Note:  $\text{U}_3\text{O}_8$  content of samples are: AMD-U5= 63.5%; AMD-U6= 66.7%;

# MICROWAVE ASSISTED DETERMINATION OF FEO IN TOURMALINE

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## ABSTRACT

Iron is one of the most important constituents of geological materials. Information about different oxidation states of Fe such as FeO and Fe<sub>2</sub>O<sub>3</sub> has to be known for classification and structural formula elucidation of rocks and minerals [1]. Determination of total iron content can be achieved by a gamut of analytical methods including classical Gravimetry, titrimetry, and instrumental techniques like spectrophotometry, AAS and ICP-AES. However, there are two potential interferences arise during sample preparation which could invalidate any subsequent measurement. The first is due to the splinters of iron when sample is crushed and other due to atmospheric air oxidation during final stages of sample grinding. Different authors have demonstrated the separation and analysis of FeO in rock and mineral samples by wet chemical methods. The widely accepted methods universally are Wilson's method and Pratt's method [2]. Some advances have been made in the quantitative identification of oxidation states with Mossbauer spectroscopy and X-ray fluorescence Spectroscopy [3].

Tourmaline mineral group is chemically one of the most complicated group of silicate minerals. Its composition varies widely and general formula can be written as XY<sub>3</sub>Z<sub>6</sub>(T<sub>6</sub>O<sub>18</sub>) (BO<sub>3</sub>)<sub>3</sub>V<sub>3</sub>W where X=Ca, Na, K & Y=Li, Mg, Fe<sup>2+</sup>, Mn<sup>2+</sup>, Zn, Al, Cr<sup>3+</sup>, V<sup>3+</sup>, Fe<sup>3+</sup>, Ti<sup>4+</sup>, Z=Mg, Al, Fe<sup>3+</sup>, Cr<sup>3+</sup>, V<sup>3+</sup>; T=Si, Al, B; B=B; V=OH, O; W=OH, F, O. [4]

In the present study FeO was determined in tourmaline mineral by conventional Pratt's method. However, the values obtained were far too low (2-3 % by wt.) when compared to the reported values in literature [5] by XRF (10-13 % by wt.). It was observed during the sample digestion that it was not completely attacked and black grains were visible. Thus an attempt was made to digest the sample with Microwave assisted reaction system (MARS-5 from CEM Corporation, USA). The reagents used were similar to that used in conventional Pratt's method. Making use of the inherent advantages of the closed microwave digestion, the parameters were optimized as regards the amount of sample, power, ramp time and temperature and hold time. It was found that for 0.2g of sample when digested with 10 ml (1:1) H<sub>2</sub>SO<sub>4</sub> and 5 ml HF (40% v/v) at 200°C with a ramp time of 10 minutes and hold time of 3 minutes complete dissolution of sample was achieved. The resulting digestate was immediately transferred to a beaker containing saturated boric acid and acid mixture (H<sub>2</sub>SO<sub>4</sub> and H<sub>3</sub>PO<sub>4</sub>) and titrated with 0.05 M K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub> using barium diphenyl amine sulphonate indicator. The method was validated with the analysis of a Canadian standard reference material MRG-1 (CCRMP), in the absence of the reference material for tourmaline. This method was used in determining of FeO in a number of samples. The Table 1 below depicts the results obtained for a few samples and compares with that of conventional Pratt's method.



**Table. 1** : Comparison of % FeO value In Tourmaline & reference standard.

S. No	Sample name/nature	% FeO(by conventional Pratt's method)	% FeO(by present method)
1	Tour-1	2.86	9.45±0.21
2	Tour-2	2.52	5.89±0.20
		<b>Certified value</b>	
5	MRG-1	8.63*	8.65±0.20

\*certified value, Canadian Certified Reference Materials Project (CCRMP)

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## DETERMINATION OF TRACE TOXIC ELEMENTS IN PLANT SAMPLES BY ICP-MS AND GF-AAS

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### ABSTRACT

Geochemical surveys based on the systematic sampling and trace analysis of a wide range of naturally occurring materials like rock, soil, stream sediment, waters etc. constitute an integral part of the uranium exploration programme. Vegetation (Geo-botanical) surveys though not very common, also yield valuable information to the exploration geologist. These surveys rely on the fact that metals may be taken up by the roots from metal-rich soil or rock and migrate to various parts of the plant or tree and the analysis of the leaves, twigs, seeds etc. may then show anomalous concentrations of those metals. Hence, plant samples collected during the course of uranium exploration need to be analyzed for uranium and several other indicator/path finder elements like As, Pb, Mo, V and Se etc. Analyses of plants also render important information in agricultural, toxicological and environmental investigations. In order to evaluate, minimize, and avoid adverse effect of toxic metals in ecosystems, one has to monitor their distribution, accumulation and dispersion in different types of vegetation.

In view of all the above, there is a need to develop/standardize accurate and precise analytical methods to determine these trace/toxic elements at very low levels (ppb and sub-ppb) in plant matrices. But, there is a paucity of analytical methods for plant analysis mainly because most of the commonly available analytical techniques do not have detection limits low enough for determination of these elements in plant materials. ICP-MS and GF-AAS are some instrumental techniques being applied for plant analysis as they possess excellent sensitivity and very low detection limits required for these analyses.

In the present work, , Inductively Coupled Plasma Mass Spectrometry (ICP-MS) and Graphite Furnace-Atomic Absorption Spectrometry(GF-AAS) have been applied to the determination of lead, arsenic and cadmium in plant samples using two different sample decomposition procedures, one employing dry digestion method and another a microwave assisted digestion method. Eight samples constituting bark, husk, and leaves of wheat, mustard and cotton plants originating from different areas in and around potential uranium deposits were analysed and the amounts of some toxic trace elements viz. arsenic(As), lead(Pb) and cadmium (Cd) present were determined. Dry digestion method involved ashing of the sample in a muffle furnace at 550°C for one hour to remove the organic matter present, followed by open dissolution of the metallic ash obtained in a mixture of HF(40%) and concentrated nitric acid(16M) on a steam water bath with the final dissolution in 3% HNO<sub>3</sub>. Microwave assisted digestion involved dissolution of the sample in a mixture of HF(40%) and nitric acid(16M) taken in a closed teflon vessel in a microwave oven ( Model: MARS , CEM make) The samples were digested at temperature of 100°C at maximum power of 600 W with 500psi pressure held for 10minutes and temperature increased to 150°C and held for another 10 minutes and finally temperature increased to 200°C and held for another 15minutes. After digestion, the sample was transferred to a platinum dish and evaporated to dryness and then treated with three times HNO<sub>3</sub> on water bath and finally dissolved in 3% nitric acid. The solutions were analysed by both ICP-MS (Model: Micromass Platform-XS) and GF-AAS (Model : Analytik jena : Zeenit 650 attached with an autosampler MPE60). Pb and Cd were measured at a wavelength of 283.3nm and 326.1 nm respectively using ammonium dihydrogen phosphate (1%) as a matrix modifier and As was measured at a wavelength of 193.7 nm using palladium nitrate (0.1%) as a matrix modifier by GF-AAS. Pb, As and Cd were determined by ICP-MS using <sup>208</sup>Pb, <sup>75</sup>As and <sup>114</sup>Cd isotopes.

Since the dry digestion method involved ashing at high temperature, followed by open vessel digestion, studies were carried out to assess the extent of loss /recovery of the analytes being determined. For this, synthetic mixtures containing known amounts of As, Pb and Cd as well as some USGS certified reference materials GXR-1 ( Jasperoid) & GXR-4 (copper Mill-head) were subjected to dry digestion procedures followed by ICP-MS/GF-AAS determination and the recoveries calculated. It was observed that >95% recoveries were obtained for all the three analytes and there was no significant loss due to volatilization during ignition and open vessel digestion.

Since, matrix effects play a significant role in GF-AAS determinations and there are limits on TDS levels for ICP-MS determinations, solutions of the plant samples were analyzed for major and minor constituents present. The results obtained are given in table 2. The range of major elements present in the plant samples was Al [92 -1281ppm), Ca [0.3 – 3.12 5 %), Fe [308 – 2073 ppm], Mg [532 -4066 ppm], Mn [ 25 -139 ppm], Ti [ < 3 – 25 ppm], Na [160 - 4780 ppm], K [0.32 – 1.64 %]

Determinations by ICP-MS and GF-AAS were carried out after appropriate dilution taking into consideration the amounts of major/minor constituents present.

The results obtained for the determination of Pb, As and Cd are tabulated in table 1, 2 and 3 respectively. It was observed that the values obtained by both the methods of dissolution agreed well indicating quantitative recovery of analytes by both methods employed. Though several workers have reported sample decomposition using only nitric acid or a mixture of nitric acid with hydrogen peroxide,<sup>(1,2)</sup> the authors could not achieve quantitative recovery with only nitric acid in the present work. Hence, HF was also used during sample decomposition. This could probably be attributed to the retention of the analytes by the silicate matrix present. The plant samples analysed showed Pb in the range of 371 - 1151 ppb, As in the range of 680 – 2200 ppb and Cd in the range of < 20 – 220 ppb ( Tables -1,2,3). The results also show that there is a good agreement between the values obtained by ICPMS and GFAAS.

Both the proposed sample digestion methods for the analysis of plant samples are effective in achieving complete dissolution recovery of Pb, As and Cd in plant samples. The methodology involved is simple and hence, suitable for a routine analytical laboratory tasked with the analysis of a large number of samples.

## References :

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2. Sample Preparation for the Determination of Metals in Food Samples Using Spectroanalytical Methods - A Review - Maria das Graças Andrade Korn et al. , Applied Spectroscopy Reviews, 43: pp. 67–92, 2008

**Table. 1 :** Results obtained for determination of Pb in plant samples

S.No	Sample type	Dry digestion		*MW digestion	
		ICPMS (ppb)	GFAAS (ppb)	ICPMS (ppb)	GFAAS (ppb)
1	Plant Bark -1	1148	1123	1017	1151
2	Plant Bark-2	782	851	725	840
3	Plant Bark-3	380	410	400	439
4	Mustard husk	300	335	326	312
5	Wheat husk	420	449	441	386
6	Tuwar dal plant	990	800	920	923
7	Cotton Plant	500	530	510	543
8	Wheat plant	420	400	412	371
		*MW- Microwave			

**Table. 2 :** Results obtained for determination of As in plant samples

S.No	Sample Type	Dry digestion		MW digestion	
		ICPMS(ppb)	GFAAS (ppb)	ICPMS (ppb)	GFAAS (ppb)
1	Plant Bark -1	710	730	756	689
2	Plant Bark-2	2200	1911	1951	1923
3	Mustard husk	1500	1590	1546	1576
4	Wheat husk	1400	1490	1409	1337
5	Tuwar dal plant	1300	1255	1236	1277
6	Cotton Plant	700	680	750	736
7	Wheat plant	1200	1087	1050	1108

**Table. 3 :** Results obtained for determination of Cd in plant samples

S.No	Sample Type	Dry digestion		MW digestion	
		ICPMS(ppb)	GFAAS (ppb)	ICPMS (ppb)	GFAAS (ppb)
1	Plant Bark-1	125	133	130	120
2	Plant Bark-2	<20	<50	<20	<50
3	Plant Bark-3	125	135	128	119
4	Mustard husk	200	182	220	211
5	Wheat husk	<20	<50	<20	<50
6	Tuwar dal plant	<20	<50	<20	<50
7	Cotton Plant	<20	<50	<20	<50
8	Wheat plant	<20	<50	<20	<50

## WAVELENGTH-DISPERSIVE X-RAY FLUORESCENCE SPECTROMETRIC DETERMINATION OF URANIUM AND THORIUM IN GRANITIC ROCKS

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### ABSTRACT

Granitic rocks are an important source of uranium and thorium. Vast granitic terrains in Peninsular and Extra-Peninsular India remain uncharacterised geochemically. Therefore, it is essential to delineate granitic rocks that are anomalously enriched in uranium and thorium.

This paper has two objectives: First, to propose a simple, accurate, precise, and rapid technique for determining uranium and thorium in granitic rocks by wavelength-dispersive x-ray fluorescence spectrometry (WDXRFS), and secondly, to discuss the accuracy, precision, lower limits of detection, x-ray spectral-line interferences, inter-element effects, speed, advantages, and limitations of the proposed technique. The technique uses a sequential x-ray fluorescence spectrometer, 100 kV - 80 mA - 3 kW x-

ray generator, rhodium x-ray tube, LiF 220 analysing crystal, fine (150  $\mu\text{m}$ ) collimator, air path, scintillation detector, and short counting times. Aliquots of 1-g of minus 300 mesh powders of granitic rocks are pelletized, with boric acid as a backing, at a pressure of 2500 kg/cm<sup>2</sup> in a hydraulic press to give powder-pellets of 41 mm diameter.

The analytical standards for determining uranium in granitic rocks consisted of a uranium-free granitic rock, spiked with spectrographically-pure uranium oxide, to give standards with uranium-concentrations ranging from 7.1 to 14508.4 ppm. The international granitic rock standards, G-2, GSP-1, GA, GH, and GS-N, were used as analytical standards for determining thorium in granitic rocks. Powder-pellets were made from 1-g aliquots of the analytical standards, following the same procedure as for the samples.

The instrumental parameters for determining uranium and thorium in granitic rocks using a rhodium x-ray tube are given in the following Table:

Sl.No.	Z	Radiation	kV	mA	Peak $2\theta$ ( $^{\circ}$ )	Background $2\theta$ ( $^{\circ}$ )	
						(1)	(2)
1	92	UL <sub><math>\alpha_1</math></sub>	70	14	37.30	36.80	38.65
2	90	ThL <sub><math>\alpha_1</math></sub>	70	14	39.23	38.48	40.18

**Other parameters are as follows :** Analysing crystal: LiF 220.

**Collimator :** Fine (150  $\mu\text{m}$ ). Path: Air. Detector: Scintillation counter.

**Counting :** Fixed time. Three readings of 20s each for peak, background-1, and background-2, involving a total counting time of 180s per powder-pellet.

The accuracy of the proposed technique is excellent (within 1% for uranium and within 3% for thorium). The precision is also excellent (within 1% for uranium and within 2% for thorium). The lower limits of detection are 2 ppm for uranium and 4 ppm for thorium. The time taken for determining uranium and thorium in a batch of twentyfour samples of granitic rocks, for a replication of four analyses per sample, by one operator, using a manual wavelength-dispersive x-ray fluorescence spectrometer, is only twelve hours. With a fully-automated, computer-controlled WDXRF spectrometer system with multiple sample-holders, capable of operating round the clock, the speed of analysis can be increased enormously.

## ISAG THE LONG JOURNEY 1993-2011

An article published by Dr. Balk in the Journal of Geological Society of America (JGSA) in 1961 on the subject of *geochemistry* has geared up my academic journey in this field. As a research student, I was so impressed by the article that I wrote a chapter on geochemistry in my Ph.D thesis entitled “The evolution of plutonic rocks of Kannegiri hill area, Khammam district, Andhra Pradesh, India” (Osmania University, 1966). Since then, none of my efforts went waste during *the journey* of my pursuit in refining my knowledge in geochemistry as well as strengthening this field in the country.

Meeting Dr. K. H. Wedepohl (Germany) in 1972 during the first International Symposium on Geochemistry (organized by Prof. R. C. Sinha, Patna University) was like an energy-booster for me. The Symposium proceedings furthered my interest in this field. A seed was sown in my mind to develop the field of geochemistry in Osmania University. Not that the geochemistry was not known in the nation but it was in an elementary stage. Very few individuals attempted to know the rudiments of this fascinating field.

Subsequently, I took a Post Graduate Diploma from ITC , the Netherlands. After a two-year study I was also trained in instrumentation in Delft Technological University, University of Amsterdam, East Germany (**Carl Zess** ), etc. The Dutch Govt. offered a two year (1974-1976) Fellowship for my studies. During this period, I had an opportunity to meet eminent professors, earth scientists and funding agencies in Holland and I tried to get a research project to continue my studies and develop the field in India. I have spent all my energy and my meager savings for traveling all over Holland, visiting various institutes to meet people for a research project.

Professor R. D. Schuiling of Utrecht University, Netherlands, a well known geochemist was one of my important contacts. I met him in 1975 with the help of Dr. Bhalla of Leiden University. Fortunately, I was successful in finalizing with Prof. Schuiling a research project entitled “A collaboration in Applied Geochemistry (R & T) between Osmania University and Utrecht University” with 100% aid from Holland in 1976. It took six months for me to materialize the project. On my return to India in 1976, it took another two years of strenuous efforts to start the collaboration. My simultaneous efforts with the Ministry of Steel and Mines, Government of India to rope in Geological Survey of India (GSI) in the research programme were also successful, and consequently the project was renamed as “Collaboration Programme in Applied Geochemistry (R & T) between Osmania University, University of Utrecht and Geological Survey of India”.

Thus, I was able to establish a full fledged center of Applied Geochemistry (R & T) in Osmania University in October 1978 with the financial support from Utrecht University, Netherlands and I was appointed as Chief Project Coordinator of the collaboration. It was the starting point for several research projects which were successfully completed and reports submitted to the concerned organizations. The collaboration was highly successful with the support and guidance of Prof. Schuiling and immense cooperation extended by the Government of Andhra Pradesh as well as earth scientists from India and abroad. It was like a bridge from east to west.

The project with full-fledged infrastructure was transformed as the Department of Applied Geochemistry with fourteen staff members and an independent new building was constructed for the Department in 1991. The Department of Applied Geochemistry in Osmania University got financial support from the Government of Andhra Pradesh and since then, the Department started offering Post-Graduate and Ph.D programs in Applied Geochemistry, a no-parallel-department of its kind in India! Furthermore, the research results of the project were impressively presented and shared with national and international academia in the International Symposium on Applied Geochemistry -first ever held in India during 1991.

The department started with a regular two year M Sc Course in Applied Geochemistry and a three semester M.Sc. (Tech) Course in Applied Geochemistry for Post Graduates in geology and geophysics during my tenure. Then I diverted my efforts to form a Society of Applied Geochemists in India. Board of Studies in Applied Geochemistry with eminent Earth Scientists as members drawn from all over India, under my Chairmanship took a resolution in 1993 to form the Society. The formation of Society was also discussed in the Faculty of Science, Osmania University for necessary approval but it did not materialize. I was preoccupied with teaching, guidance of Ph.D students and other academic work of the department including an international collaboration programme in Applied Geochemistry. The pressure of work in organizing new courses and conducting examinations in the department left very little time for me to start the Society and there were various impediments. Meanwhile, I got unexpected relief from the administrative and academic duties of the department. Immediately, I grabbed the opportunity to pursue my dream of establishing the Society of Applied Geochemists at national level. I was fortunate to receive encouragement, cooperation and solid support from the national organizations like AMD, GSI (SRO), NGRI, DOD (MOES), NMDC, ONGC, etc. and also from a few universities in south India. This strengthens my belief the of one door is closed. The Almighty opens another door in life.

A Core Committee (CC) was then constituted with Dr. K.K. Dwivedy, Director, AMD as Chairman and I, as the Convener, to work out the modalities to form the Society. The CC took a decision to establish an autonomous Society of Applied Geochemists at national level and register it under the societies act. Accordingly, a draft constitution was prepared and presented by me to the CC for approval.

The CC members were Dr. K.K. Dwivedy, (Director, Atomic Minerals Division), Dr. H.K. Gupta (Director, National Geophysical Research Institute), Dr. S.K. Ghosh (Dy. Director General, Geological Survey of India), Dr. N.K. Rao (Bhabha Atomic Research Centre), Dr. A.K. Chatterjee (National Mineral Development Corporation Limited), Dr. S.N. Sahay (Mineral Exploration Corporation Limited), Dr. S.M. Naqvi, Dr. V. Divakara Rao (National Geophysical Research Institute), Dr. R.S.N. Sastry, Mr. Gautam Roy (Osmania University) and the Convener is myself.

The CC met in AMD under the chairmanship of Dr. K.K. Dwivedy and the draft constitution prepared by me was discussed and approved. With the approval of the Constitution of the Society in the General Body meeting held on 4<sup>th</sup> April 1997, the Society was finally officially born after a few labour pains. Subsequently the society was registered with the Registrar of Societies, Government of Andhra Pradesh as the **Indian Society of Applied Geochemists (ISAG)**. A big relief for me then, just as the reader of this 'the journey' !! I hope this will help young scientists for new ideas

ISAG organized its first International Symposium on Applied Geochemistry in 1991 followed by a National Symposium in 1999 and released *the first issue* of the *Journal of Applied Geochemistry (JAG)*. The Executive Council (EC) started implementing some of the important resolutions passed in the General Body meeting held on 3<sup>rd</sup> April 1998. Thus, the National Symposium on “Applied Geochemistry -Retrospect & Prospect” was organized in 19-21 January 1999, as one of the main resolutions of AGM. As an ongoing academic activity, the Society organized an International Symposium on “Applied Geochemistry in the Coming Decades” during 10-12 August 2001, National Symposium on “Applied Geochemistry in Exploration for Minerals and Oil” during 10-11 September 2003, International Symposium on “Applied Geochemistry in the Evaluation and Management of Onshore and Offshore Geo-resources during 28-30 September 2005, and National Symposium on “Applied Geochemistry of Energy Resources and Precious Metals” 19-20 September 2007, International Symposium on “ Carbon Management & Climate Change and Role of Applied Geochemistry” during 25-27 November 2009 and now with a National Symposium on “Recent Advances in Applied Geochemistry: Current Status and Future Trends” scheduled during 19-21 October 2011.

The seven Symposia organized by ISAG were highly successful and all the proceedings were published in the *Journal of Applied Geochemistry (JAG)* as special volumes. The eighth symposia to be held in October 2011 will hopefully be taken up with renewed zeal and enthusiastic success.

The ISAG organized its first AGM at National Institute of Oceanography (NIO), Dona Paula, Goa on invitation during March 2005, the first ever AGM held outside Hyderabad; the next AGM-2006 was held in Wadia Institute of Himalayan Geology (WIHG), Dehradun during March 2006, third AGM at Geological Survey of India (GSI), Jaipur during February 2007, fourth AGM at Madras University, Chennai during February 2008 and fifth AGM at University of Mysore, Mysore during February 2009, fifth AGM at Pondicherry University, Port Blair, Andaman during February 2010 and the sixth AGM at the School of Earth Sciences, Swami Ramanand Teerth Marathwada University (SRTMU), Nanded during January 2011. The next AGM is going to be held at Banaras Hindu University (BHU), Varanasi during February 2012.

Organizing AGMs at the national level is one of the important aims and objectives of the society, with AGM at NIO, we are able to fulfill one more resolution of ISAG. The AGM held at NIO was a milestone in the short history of ISAG. Four medals were instituted to be awarded annually from 2005; they are instituted by Prof. K. Surya Prakash Rao (two medals), Dr. R. Dhana Raju (one medal) and Dr. K. K. Dwivedy (one medal). The details of these medals are incorporated elsewhere in this Abstract Volume.

The Annual General Body Meetings (AGMs) are always associated with national seminars and the proceedings are published regularly.

As a convention, the National Symposium on “Recent Advances in Applied Geochemistry: Current Status and Future Trends” has been announced during early 2011 to be scheduled for 19-21 October 2011 and the response for the symposium, as expected, is satisfying.



The excellent cooperation from Atomic Minerals Directorate for Exploration and Research (AMD), National Geophysical Research Institute (NGRI), National Mineral Development Corporation Limited (NMDC), Oil & Natural Gas Corporation Limited (ONGC), and Oil India Limited (OIL) as joint organizers has not only helped the ISAG but also enhanced its prestige and stature.

The Executive Council of ISAG is grateful to all those who struggled for its growth to the present stage.

I am extremely grateful to AMD, CSIR, DAE-BRNS, GSI, MoES, NGRI NMDC, ONGC, OIL, and others for the cooperation and support extended for the success of this National Symposium 2011.

On behalf of EC and my own behalf we promise that ISAG will work sincerely to implement the contemplated aims and objectives with your continued encouragement, participation, contribution and cooperation. We appreciate and encourage institution new Medals with ISAG for good work published in the Journal of Applied Geochemistry.

Let us rededicate ourselves to effectively contribute to the journey of the Applied Geochemistry on the living earth and other parts of this solar system.

Date: 17-10-2011

K. Surya Prakash Rao  
Secretary