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EDITOR’S COLUMN

The Mines and Minerals (Development and Regulation) Amendment Act, 2015 aims to legalize the system of auction of mines to enhance transparency in mineral allocations in India. Though the act is being considered as a welcoming change in the mining sector which has allegedly been entangled in controversies, there are a few questions which are causing worries among the integrated mining companies. Under the British Raj a committee of experts formed in 1894 formulated regulations for mining safety and ensured regulated mining in India. The Act of 1957 was amended many times during 1958, 1960, 1972, 1978, 1986, 1994, 1999, 2010 and 2012. In January 2015, Mines and Minerals (Development and Regulation) Amendment Act, 2015 was promulgated to amend the original Act. The Act specifies the requisites for obtaining and granting mining leases for minerals and streamlines a number of provisions related to minerals and mining.

The bill introduced paraphernalia of auctions to allocate mining licenses. The lessee of a mine after 50 years will have to go home if he fails to win the competition in the auction where bigger players will call the shots. In such a scenario, small players will find it tough to survive.

It provides for a fixed percentage of the revenue from a mine will be allocated to the development of the surrounding area, termed District Mineral Foundation. The state government is empowered to set the rates and it will be in addition to the royalty. A National Mineral Exploration Trust has been set up to explore and promote non-coal minerals and it will be funded by a 2% levy from mining license holders. The levy of tax to the state governments in the form of District Mineral Foundation is seen by the mining companies, in general, as an additional burden. The royalty for the minerals like iron ore, chromite, zinc, lead and silver are already high at 15%. They feel that extra levies will impact the cost component of their products to a considerable extent. Most of the major clauses remain unchanged, there are, however, a few crucial additions/ exceptions which are expected to improve the mining laws and intends to put a check on illegal mining. The act has transferred considerable regulatory claws to state government in granting mining leases, and at the same time provided for relevant remote control from the Central Government on selected matters.

In a bold attempt Mr. B. K. Mohanty, Advisor, SGAT has helped to provide a platform to the stake holders of Mining Industry to give vent to their woes in wobbly running of the mines. The deliberations were candid and healthy and will be constructive if the resolutions arrived at in the valedictory session are paid heed by the corridors of power. The health of the mining industry will be reflected in the sustenance of the environment and development of its surrounding area.

Dr B M Faruque
Editor

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WHAT IS ENVIRONMENTAL EDUCATION?

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ABSTRACT

The concept of Environmental education originated in ancient human civilization and people's awareness was based on moral and ethical values, and narration through fables for children. The roots of environmental education can be traced back to Vedic Times 'Rakhaye Prakrutim Pantu Loka'.In eastern culture; importance of nature study (first phase) started in Guru Ashrams but did not take a concrete shape to develop a curriculum for the schools and colleges to address the problems. However, nature was considered as the expression of the Almighty. People worshiped Sun, Moon, Planets, Trees, Rivers, and Soil, some animal species etc.

Manusmruti comprises 2684 verses in 12 chapters. The treatise focused on environmental protection and gave a meaningful structure and is deductive. These ethical laws had significant effect in post vedic period to protect trees, forests, animals, and the five gross elements such as the Ether (Aakaassa), Vaayu (Air), Tejas (Fire) Aaapa (Water) and Kshiti (Earth/ Soil) (Buhler, G. 1886). In the second phase, Vernadsky of Russia (www.rdasia.com) developed the concept of Biosphere, the zone that supports life on earth and recognised the geological force and described the atmosphere as extension of Life in 1922. James Lovelock (1919) of England proposed the Gaia hypothesis suggesting that the earth is a single living organism. The third phase dealt with systems concept and scientists tried to incorporate management aspects of natural resources for human welfare. This led to develop Environmentalism.

At present (4th phase) importance is given to Ecosystem Analysis (structural change, functional change, stress factors, stability, restoration and sustainability) and impact of anthropogenic activity and climate change on natural and man-made ecosystems.

Introduction

The roots of environmental education can be traced back to Vedic Times 'Rakhaye Prakrutim Pantu Loka'. In eastern culture; importance of nature study started in Guru Ashrams but did not take a concrete shape to develop a curriculum for school. However, nature was considered as the expression of the Almighty. People worshiped Sun, Moon, Planets, Trees, Rivers, and Soil etc. Manusmruti comprises 2684 verses in 12 chapters. The treatise focused on environmental protection and gave a meaningful structure and is deductive. These ethical laws had significant effect in post vedic period to protect trees, forests, animals, and the five gross elements such as the Ether (Aakaassa), Vaayu (Air), Tejas (Fire) Aaapa (Water) and Kshiti (earth/Soil) (G. Buhler, 1886, S. Padhy, et al, 2006). These laws have ethical and moral values but were not inductive.

In recent times as early as the 18th century, Jean-Jacques Rousseau stressed importance of an education that focuses on Environment. Several decades later, Louis Agassiz, a Swiss-born naturalist supported Rousseau's philosophy. He encouraged students to 'Study nature'. Both the scholars laid the foundation for environmental education program, known as Nature Study, which happened in the late 19th century and early 20th century. In 1876, the German Biologist, Ernest Haeckel coined a word ‘Ecology’ (Eco means House/ Home and logus means discourse). Environmental Education has a strong root in understanding ecological principles.

Initially the nature study movement used fables and moral lessons to help school students to develop an appreciation of nature as man is part of the nature (originally Eastern Concept). Anna Botsford Comstock, the head of the Department of Nature Study at Cornell University, USA, was a prominent figure in the nature study movement and wrote a Handbook for Nature Study in 1911, to educate school children on cultural values. Comstock and other leaders of Nature study movement, such as Liberty Hyde Bailey, involved community leaders, teachers, and scientists and changed the science curriculum for school children across the United States. Vernadsky of Russia (www.rdasia.com) developed the concept of Biosphere, the zone that supports life on earth and recognised the geological force and described the atmosphere as extension of Life. James Lovelock of England proposed the Gaia hypothesis suggesting that the earth is a single living organism. The biodiversity interact with the earth, each having its small effect on the system as the individual cells cause some effect on human body. Ultimately the planet is self regulating and maintains its own surface condition (www.rdasia.com).

A new type of environmental education, named Conservation Education, emerged during 1920s and 1930s. Conservation Education dealt with natural world and focused on rigorous scientific training involving scientific management and planning tool that helped to solve social, economic, and environmental problems during that time.

In 1935, a British biologist, A. G. Tansley extended the system concept (Figure-1), developed in 16th century by William Harvey, a human physiologist and a few physical scientists, to Ecology, the mother of Environmental Science (Dash and Dash, 2009). Figure-1(a) shows the component parts of a natural ecosystem and Figure-1(b) shows the flow of energy and matter between the component parts of the natural ecosystem using ecological symbols (Dash and Dash, 2009).

He thought the living cell is a tiny system and its function is quantified by the resource inputs, biosynthesis, metabolism and the output (growth) etc. The quantification helps to understand the structure of functional dynamics with predictable characteristics. In this way, all type of living cells under different conditions can be quantified and compared. He extended this idea to a mega-system such as an ecological system or Ecosystem. This concept led to develop a new discipline Ecosystem Analysis. Ecosystems have been classified on the basis of energy flow (Figure-2 and 3) showing sun is the source of energy for natural ecosystems and fossil fuel and other form of energy have become the source of energy for man-made systems. Man-made systems are usually monospecies, higher rate of productive, fragile, pollution generating, etc.

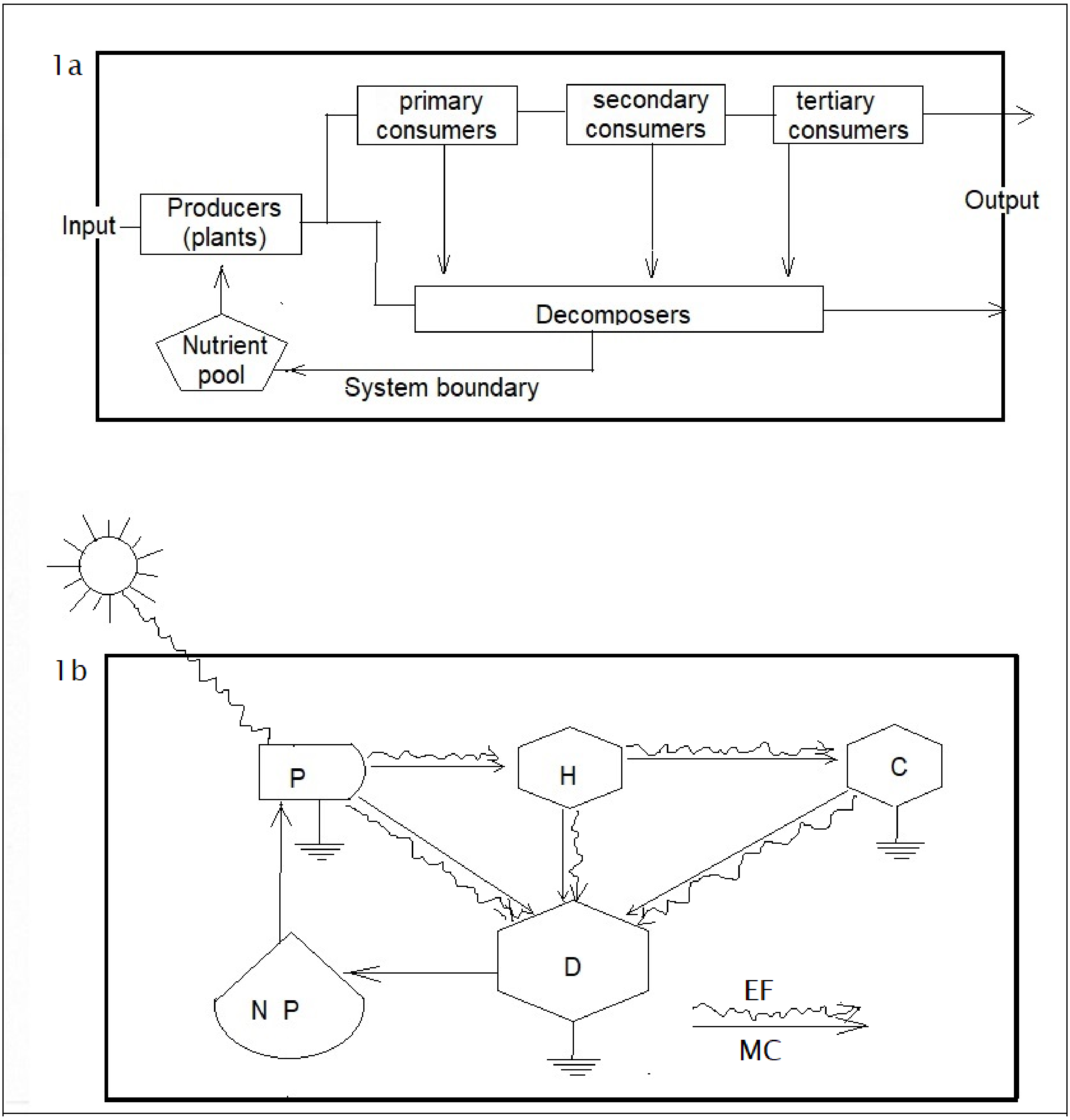

Figure-1: (a) Ecosystem visualised as a single block design (Abiotic and biotic components and their interactions are visualised.)
(b) An ecological system boundary, component parts, energy flow and matter cycling
(S=Sun, P=Producers, H=Herbivores, D=Decomposers, NP=Nutrient Pool, EF=Energy Flow & MC=Matter Cycling)

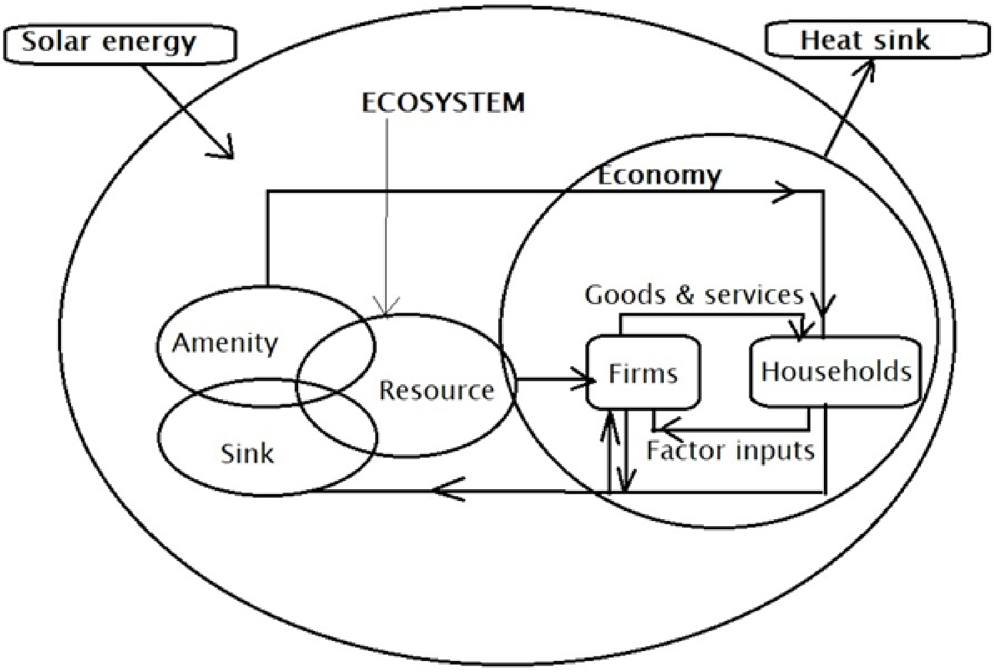

Figure-2: Eco System

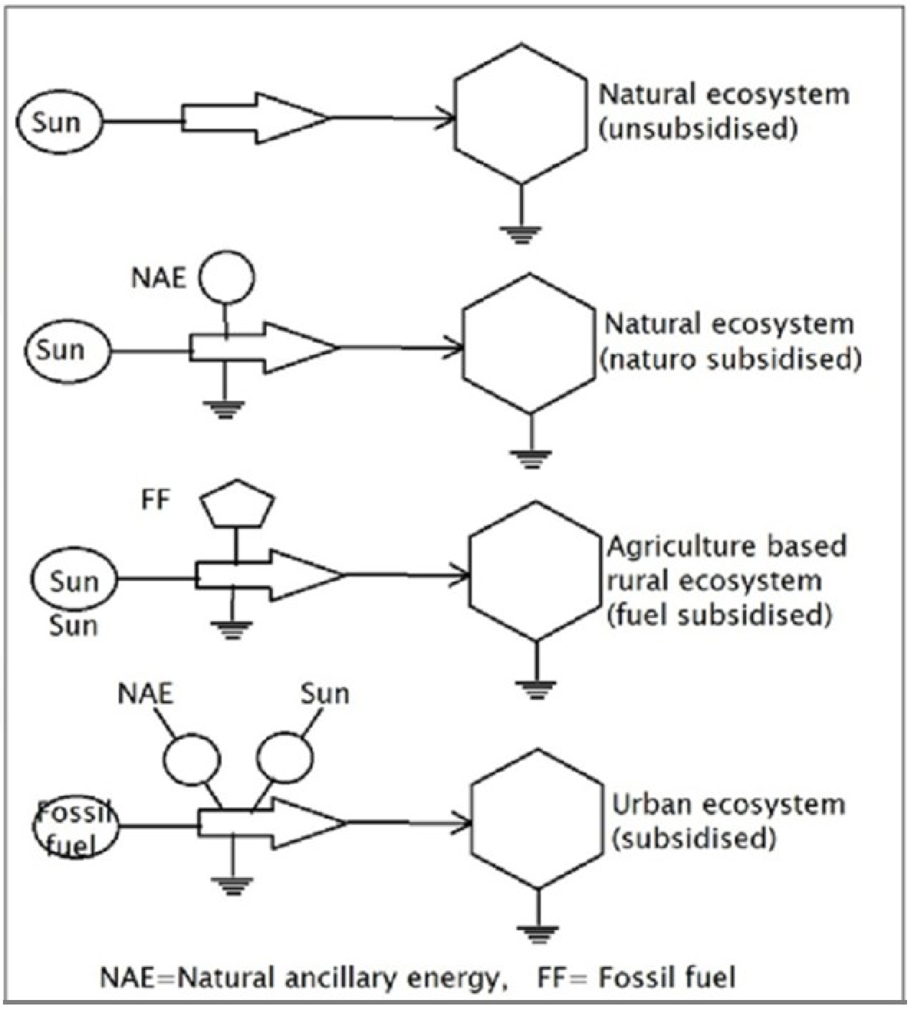

Figure-3: Graphical model of systems

Modern Environmental Education Movement

The modern environmental education movement, gained significant momentum in the late 1960s and early 1970s, as more people began to fear the fallout from radiation, significant amounts of air and water pollution and solid and liquid waste generation, chemical pesticides mentioned in Rachel Carson's 'Silent Spring', the minamata disease due to mercury pollution, forest clearance for developmental projects and public's concern for their health and the health of their natural environment. This led to a unifying movement known as 'Environmentalism'. We are aware of Chandi Prasad Misra movement ably supported by Sunderlal Bahuguna (Chipko movement) to protect forests in Uttarakhand by hugging the trees and not allowing forest contractors to cut the trees, the 'Narmada Bacchao' movement, 'The Gandhamardan movement' not allow mining of bauxite ore by Balco Company etc. These are examples of Environmentalism.

Environment houses resources and is an enabler to provide livelihood support sustainably if protected and managed scientifically. Environmental education was thus born of the realization that solving complex local, regional and global environmental problems cannot be accomplished by politicians and experts alone, but requires "the support and active participation of an informed public in their various roles as consumers of resources, employers, business and community leaders and voters.

The Images-1, 2, 3A and 3B are natural diverse ecosystems but they are multispecies, (types of species are different), stable, having complex food web, largely non-polluting, solar energy dependent ecosystems. They have the similar component parts as described above. They provide resources, especially Bio-resources to human beings in sustainable manner. Manmade ecosystems (Image-4) are energy intensive, pollution generating but highly productive and fragile. These are usually monospecies/ no species systems. They are not sustainable unless scientific and resource management are practiced. These are (i) Agro ecosystems, (ii) Aquaculture systems, (iii) Industrial systems, (iv) Urban systems etc.

These systems require huge amount of energy, resources and labour for their running. These systems, however provide jobs and productive, although they generate pollutants that create health hazards.

A definition of "Environmental Education" first appeared in The Journal of Environmental Education in 1969, authored by William B. Stapp, who later went on to become the first Director of Environmental Education for UNESCO. Simultaneously, another first articles about environmental education as a new movement also appeared in the Phi Delta Kappa in 1969 authored by James A. Swan.

Ultimately, the first Earth Day on April 22, 1970 paved the way for the modern environmental education movement. Later that same year, National Environmental Education Act was enacted in USA, which was intended to incorporate environmental education in Higher Secondary Schools. In 1971, the National Association for Environmental Education (now known as the North American Association for Environmental Education) was established to improve environmental literacy by promoting environmental education programs.

Image-1: A Forest Ecosystem in Odisha, India (provide with diversified niches to biodiversity, food, fodder, Ayurved medicine, human habitation material etc to Man)

Image-2: A prairie Grassland Ecosystem (provide fodder, grazing land etc to Man and Cattle)

Image-3A: Chilika-Nalabana ecosystem

Image-3B: A natural mangrove ecosystem Bhitarkanika (rich in biodiversity)

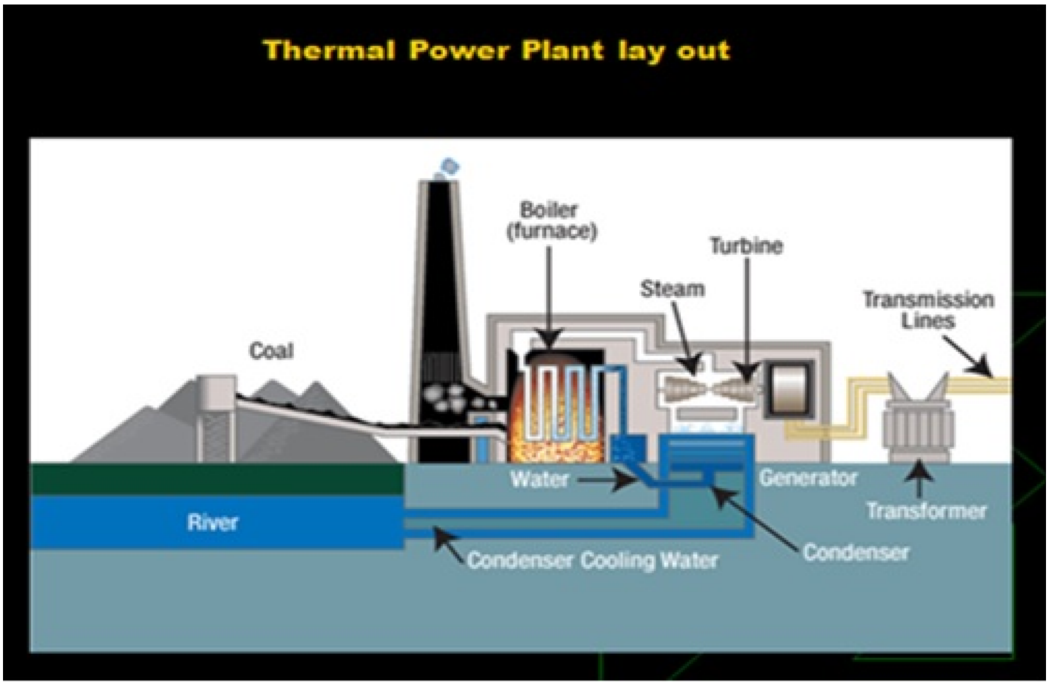

Image-4: A man-made system, heavy resource input (mainly water and coal), cause huge pollution.

Internationally, environmental education gained recognition when the UN Conference on the Human Environment held in Stockholm, Sweden, from June 5 to 16, 1972, declared environmental education must be used as a tool to address global environmental problems. The United Nations Education Scientific and Cultural Organization (UNESCO), and United Nations Environment Programme (UNEP, 2011)created three major declarations that have guided the course of environmental education. In India in late 1990s, the Supreme Court ordered to introduce Environmental Studies in +3 level in undergraduate studies.

Stockholm Declaration, June 5-16, 1972: The Declaration of the United Nations Conference on the Human Environment. The document was made up of 7 proclamations and 26 principles "to inspire and guide the peoples of the world in the preservation and enhancement of the human environment."

Belgrade Charter, October 13-22, 1975: The Belgrade Charter was the outcome of the International Workshop on Environmental Education held in Belgrade, Yugoslavia (now Serbia). The Belgrade Charter was built upon the Stockholm Declaration and detailed the objectives, and guiding principles of environmental education programs, for schools and for general public (wikipedia.com).

Tbilisi Declaration, October 14-26, 1977: The Declaration "noted important role of environmental education in the preservation and improvement of the world's environment, as well as in the sound and balanced development of the world's communities." The Tbilisi Declaration updated ‘The Stockholm Declaration’ and ‘The Belgrade Charter’ by including new goals, objectives, characteristics, and guiding principles of environmental education (wikipedia.com).

The components of environmental education are:

- **Awareness and sensitivity** to the environment and environmental challenges,
- **Knowledge and understanding** of the environment, Ecosystems, and environmental challenges,

- **Attitudes** of concern for the environment and motivation to improve or maintain environmental quality,
- **Skills** to identify and help resolve environmental challenges,
- **Participation** in activities that lead to the resolution of environmental challenges

Environmental education does not advocate a particular viewpoint or course of action. Environmental education teaches individuals how to weigh various sides of an environmental issue through critical thinking and it enables them in solving their problems and decision-making skills. Environmental education increases public awareness and knowledge of environmental issues, provides facts about environmental issues and enhances individual problem solving capability, Environmental education (EE) involves organized efforts to teach how natural environments function, and particularly, how human beings can manage ecosystems to live sustainably. Environmental Science and Education is a multi-disciplinary field integrating disciplines such as biology, especially ecology, earth system science (geology, geography), chemistry, physics, atmospheric science, and mathematics. However, environmental education must include efforts to educate the public and print media, websites, media campaigns, et solutions to these issues. The UNESCO states that EE is vital in imparting an inherent respect for nature amongst society and in enhancing public awareness. UNESCO emphasizes the role of EE in safeguarding future global developments of quality life through the protection of the environment, eradication of poverty, minimization of inequalities and insurance of sustainable development (UNESCO, 2014a, b).

Focus on Environmental education: The focuses are on:

1. Engaging with citizens of all ages to;
2. Think critically, ethically, and creatively when evaluating environmental issues;
3. Make educated judgments about those environmental issues;
4. Develop skills and a commitment to act independently and collectively to sustain and enhance the environment; and,
5. To enhance their appreciation of the environment; resulting in positive environmental behavioural change (Bamberg & Moeser, 2007);

An Environmental education curriculum to explore the human-nature relationship

Environmental Education encourages the discovery and understanding of the Earth's natural systems (Forests, Grasslands, Lakes, Geo-systems, and Bio-systems etc) and the human role in those systems. Environmental educators teach about the interrelationships among all living things and with surroundings. They have a solid comprehension of ecological concepts (on ecosystem productivity, energy flow, consumption patterns, matter circulation, balance of nature etc) and an understanding of environmental history and the ecological effects that humans have had on the Earth and the homeostatic mechanisms. Students pursuing this emphasis explore the literature and philosophy concerning the human–nature relationship.

Environmental educators must have ecology, environmental science, economic, political, and environmental law background in order to teach about relationships among local communities, technological society, and the local, regional and global environment. A foundation in the field of education with an understanding of learning theories, curriculum design, and experiential and field study education, appreciation of the beauty of the natural world provides them with the necessary knowledge and skills to develop their teaching and to demonstrate their competence. (Tanner, 1974).This is a big challenge.

Benefits of Environmental Education

Few important benefits are described below.

(i) **Imagination and enthusiasm are heightened in Youth.**
EE sparks the imagination and unlocks creativity among youth. When EE is integrated into the curriculum, students are more enthusiastic and engaged in learning.

(ii) **Learning transcends the classroom to the Real World**.
Not only does EE offer opportunities for experiential learning outside of the classroom, it enables students to make connections and apply their learning in the real world. EE helps learners see the interconnectedness of social, ecological, economic, cultural, and political issues.

(iii) **Skill Development and Enhancement**
EE encourages students to research, investigate how and why things happen, and make their own decisions about complex environmental issues. By developing and enhancing critical and creative thinking skills, EE helps foster a new generation of informed consumers, workers, as well as policy or decision makers. In the evolution of Environment study, the discipline has developed into two broad categories i/e. (i) Environmental Science consisting of rigorous scientific analysis of theory, field scientific studies involving monitoring, and environmental management etc; keeping human interest and sustainability in mind; (ii) Environmental studies involving society, creating awareness and sensitizing people ,especially school students and public at large.

(iv) **Tolerance and understanding are inculcated.**
EE encourages students to investigate varying sides of issues to understand the full picture. It promotes tolerance of different points of view and different cultures.

(v) **Interdisciplinary Learning**
By incorporating EE practices into the curriculum, teachers can integrate science, math, language arts, history, and more into one rich lesson or activity, and still satisfy numerous state and national academic standards in all subject areas. Taking a class outside or bringing nature indoors provides an excellent backdrop or context for interdisciplinary learning.

(vi) **Appreciating Nature's Beauty and playing for fun**
By exposing students to nature and allowing them to learn and play outside, EE fosters sensitivity, appreciation, and respect for the environment. It combats "nature deficit disorder" and it's FUN!

(vii) **Healthy lifestyles are encouraged.**
EE gets students outside and active, and helps address some of the health issues we are seeing in children today, such as obesity, attention deficit disorders, and depression. Good nutrition is often emphasized through EE and stress is reduced due to increased time spent in nature.

(viii) **Communities are strengthened.**
EE promotes a sense of place and connection through community involvement. When students decide to learn more or take action to improve their environment, they reach out to

community experts, donors, volunteers, and local facilities to help bring the community together to understand and address environmental issues impacting their neighbourhood.

(ix) **Responsible action for betterment of the environment**
EE helps students understand how their decisions and actions affect the environment, builds knowledge and skills necessary to address complex environmental issues, as well as ways we can take action to keep our environment healthy and sustainable for the future. Service-learning programs offered by PLT and other EE organizations provide students and teachers with support through grants and other resources for action projects.

(x) **Empowerment of Students and Teachers**
EE promotes active learning, citizenship, and student leadership. It empowers youth to share their voice and make a difference at their school and in their communities. EE helps teachers build their own environmental knowledge and teaching skills.

Through an interdisciplinary curriculum that covers topics such as ecosystem analysis, biodiversity, & other resources conservation, environmental thought, environmental debates, chemistry of pollution, its effects on biodiversity and man, and its abatement, climate change and environmental politics, one will gain an understanding of the theories, policies, and ethics that have shaped public discourse and understanding of our environment; examine national and local models of environmental education; analyse their relationship to contemporary issues of environmental literacy; and develop competencies in planning environmental education programs. In Indian context folk song, folk dances, Jatra, Daskathia, Pala, etc can create environmental awareness in people, especially village people.

During the last few decades development of environmental studies has grown in two interrelated aspects such as (i) the scientific and technological aspects of Environmental Science including ecosystem analysis, modelling and scientific conservation, pollution abatement and environmental management, and (ii) softer way to sensitizing people in various ways; and to abate environmental degradation by creating legal instruments. Environmental laws have now become integral part of legal education. Besides, all developmental projects before implementation are to assess the impacts the project would create if implemented and to look into the environmental management plan for sustainable development.

REFERENCES

Bamberg, S.; Moeser, G. (2007) "Twenty years after Hines, Hungerford, and Tomera: A new meta-analysis of psycho-social determinants of pro-environmental behaviour". Journal of Environmental Psychology, 27 (1), pp. 14–25.

Buhler, G, (1886) The Laws and Manu in 'The Sacred Books of the East’ (edited by F Max Muller, Oxford in Clarinda Press, London.

Dash, M. C. and Dash,. S. P. (2009) Fundamentals of Ecology, McGraw-Hill Publications, New Delhi, 562 pages.

Earthday.net

Padhy, S., Dash S. K. and Mohapatra, Ratnaprave (2006) Environmental Laws of Manu: A Concise Review, Journal of Human Ecology, 19(1), pp. 1-12.

Tanner, R. T. (1974) "Ecology, environment and education," Lincoln, NE, Professional Educators Publications

Swan, J. A. (1969) "The challenge of environmental education". Phi Delta Kappan, 51, pp. 26–28.

Stapp, W. B. et al., (1969) "The Concept of Environmental Education" *(PDF)*. The Journal of Environmental Education. 1 (1): pp.30-31.

The Belgrade Charter, Adopted by the UNESCO - UNEP International Environmental Workshop, October 13–22, 1975.

UNESCO (United Nations Educational, Scientific and Cultural Organization), 2014a, Ecological Sciences for Sustainable Development. [online] Available at http://www.unesco.org/new/en/natural-sciences/environment/ecological-sciences/capacity-building-and-partnerships/educational-materials/

UNESCO (United Nations Educational, Scientific and Cultural Organization)., 2014b, Shaping the Future We Want: UN Decade of Education for Sustainable Development. [pdf] Paris: UNESCO. Available at http://unesdoc.unesco.org/images/0023/002301/230171e.pdf

Wikipedia.com: the free encyclopedia on Environmental Education.

www.rdasia.com

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PROGNOSIS OF THINTHINI COPPER MINERALIZATION IN THE STATE OF KARNATAKA, INDIA: A MODEL OF CONCLUSIVE END RESULT SOLUTION OF BASE METAL EXPLORATION TO AN EXEMPLARY ENVIRONMENTAL PROJECT

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ABSTRACT
The copper mineralization in the meta-diabase dyke rock of Dharwar Schist belt of Thinthini area of Yadgiri district of Karnataka, India has witnessed a long geological appraisal and exploratory mining activity for a protracted period from 1889 to 2013. The ancient old working locations of the area being worked out by different exploration agencies have unfolded a large quantum of geological, drilling and exploratory mining data to convert the mineral occurrence in to a base metal deposit. But the endeavour of such geo-scientific pursuit could not establish the project to its feasibility status with minimum cut-off grade of 0.6% copper. However, the pragmatic and novel idea of environmental solution to this project could set a classic example of establishing end result of mining eco-system such as "Bio-Fuel Park" by compensating the national investment in to fructification of Model Project.

Location and Accessibility

The Thinthini (16° 23': 76° 40' E) Copper Deposit is in the Shorapur Taluk, Yadgiri Dist (Toposheet No: 56 D/11) and is located 29 km north of Hutti Gold Mines and the river Krishna flows one km to the south of the deposit. The nearest rail head is Yadgiri on the main Chennai-Mumbai broad gauge railway. There is a good road connecting Thinthini with Yadgiri, at a distance of 80 km.

Physiography

The area forms a moderately undulating flat terrain at an elevation of 471 m above MSL in the Krishna valley and is covered by black cotton soil. Rapid erosion in the neighbourhood of river Krishna has resulted in intimate dissection of the plain land into numerous hillocks of pink porphyritic granite, which are concealed beneath the black soil cover. The elevation of Thinthini above MSL is 380 m. The river Krishna flows at an elevation of 368 m above MSL. It is 700 m broad and is spanned by a bridge for a length of 1 km. The deposit under consideration forms a low mound to the east of the main highway extending in an east–west direction.

Geology

The region surrounding the deposit at Thinthini is made up mainly of pegmatites, grey and pink granitic gneisses with lenticular patches of amphibolite enclaves of 2.4-2.0 Ga age. A few diabase dykes are seen to be cutting across the above rock types and the copper mineralization is found to be associated with it.

The country rocks belong to Dharwar Group of rocks of Archaean age and their geological succession is as follows:
Dolerite dykes
Quartz (vein quartz, recrystallized)
Diabase dykes
Pegmatite
Pink porphyritic granite
Grey and pink gneisses
Migmatites and Amphibolites

The well known copper mineralisation in the Thinthini area is associated with major fault zone extending in east-west direction. The fault zone is traced for about 30 km where in numerous old workings for copper (with lot of Malachite stains) have been identified around the neighbourhood of Thinthini.

There is an east-west trending diabase dyke, which is 24 m wide and exhibits steep northerly dips and the dyke has been sheared due to the fault and intruded by quartz veins hosting copper mineralisation. Brecciation of the diabase dyke and pink granites appears to be responsible for the observed copper mineralisation.

The diabase dyke has also been subjected to shear movements. Consequently some brecciated zones have been formed mainly in the hanging wall portion of the dyke containing veins of quartz with chalcopyrite and sub-ordinate pyrite.

Description of Mineralised zone

The trend of the meta-diabase dyke broadly extends in N 85° W to S 85° E direction and dips at 80° to 85° due North. The average width of the dyke over a strike length of 2167 m is 26 m, with a maximum thickness of 40 m near the old workings at Thinthini. It narrows down to a width of 19 m when traced both to the east and west over a strike length of 16.20 km commencing from village Thinthini in the east to Hunsihal in the west. Krishnamurthy (1971) has described the dyke as a metabasalt and has traced it for a length of about 5 km in an east-west direction. He has also noted that the sheared and brecciated zones in the dyke is in continuity with the strike direction of the fault traced in the Bhimas group of rocks near Rajankollur, located about 22 km west of Thinthini.

Though the mineralization persists feebly throughout the entire length of the dyke on the surface, The width of this zone varies between 4 m to 11 m (with an average of 7 m) over a strike length of 500 m on the eastern part and 8 m to 30 m (with an average of 19 m) on the western part of the mineralized zone over 442m length.

The meta-diabase dyke is again distinguished in to two types - Barren diabase and Cataclastic diabase.

The barren diabase is least deformed and the original ophitic texture is preserved. It contains mainly chlorite (penninite variety) with altered twinned plagioclase, quartz, calcite, zoisite and specks of pyrite, magnetite and sphene. Occasional grains of flesh red microcline also occur. The veins of quartz, calcite and epidote traverse the diabase rock. Gradual variation in the grain size from coarse to fine grained can be traced from the center to the contacts especially towards the foot wall. At the contacts, the dyke shows effects of chilling and chloritization with significant mineralogical change.

The cataclastic diabase, on the contrary, is intensely sheared and fractured. The rock is excessively altered to fine grained, compact and grayish green chloritised meta-diabase and is traversed by quartz and calcite veins having sulphide minerals. The original texture has been completely obliterated. The major ore minerals are pyrite, chalcopyrite and rare bornite with secondary minerals of covellite, malachite, chalcocite and azurite. The quartz-calcite veins traversing the diabase dykes are the carriers of ore minerals like chalcopyrite and pyrite. The width of quartz veins varies from a millimeter to as much as half a metre. Crystals of quartz (rock crystal) and calcite with or without specularite and pyrite crystals are found to occur in cavities of vein quartz traversing the diabase dykes. Characteristically the old workings are mainly confined to these cataclastic diabase.

Description of Ore minerals

Ore minerals occur both in the mineralized diabase and pink porphyritic granite/ pegmatite. Chalcopyrite is always in association with pyrite and occurs as disseminations, stringers and rarely as patches in quartz veins traversing the diabase, pink porphyritic granite and pegmatite. Minor amounts of chalcopyrite are also present in the diabase itself and along shears in pink feldspar, chlorite, cataclasite and pink porphyritic granite. The ore-microscopy studies have revealed that the chalcopyrite fills fractures and brecciated faces of pyrite and the replacement of pyrite by chalcopyrite is common.

Covellite and chalcocite are the alteration products of chalcopyrite. On the western block of the mineralized zone crystals of pyrite are present in the chlorite rich portions of the porphyritic granite. Specularite occurs abundantly in the western block traversing the fractured, brecciated, silicified and epidotised diabase dyke on the hanging wall in contact with the granite.

Structural Control of Ore Localisation

Copper mineralization at Thinthini is localised mainly along the hanging wall contact of the diabase dyke, which has been intensely fractured. The hanging wall of the diabase dyke is in contact with brecciated pink feldspar-chlorite rock, pegmatite and pink porphyritic granite. This zone of fracturing and brecciation represents a steep northerly dipping fault zone along which the dyke appears to have been emplaced. Fractures in the diabase dyke and pink porphyritic granite are traversed by quartz and calcite veins which carry disseminations of chalcopyrite and pyrite. These veins vary in width from a millimeter to as much as 0.5 m.

Old workings at Thinthini are located on the mineralized diabase and can be traced for a strike length of 130 m and over a width of 10 m. Mineralized zones encountered within the boreholes, when projected on to the surface coincide with the location of old workings.

Mineralization is also seen on the foot wall contact of the dyke with the pink porphyritic granite. Here the mineralization is mainly found in pink porhyritic granite and pegmatite. However, this is on a minor scale compared to that found along the hanging wall contact.

On the western block mineralization is mainly confined to pink porphyritic granite and pegmatite within which chalcopyrite occurs in the form of disseminations in quartz veins and along chloritised shear planes. A rich but narrow zone of chalcopyrite mineralization is confined to the hanging wall of the diabase dyke near its contact with the pink granite.

Background of Exploration

Thinthini area has witnessed the mineral search from nineteenth century to recent mining activities, which are evidenced by the presence of old workings, open excavations, shafts and mine dumps etc. The old workings at Thinthini were first noticed by Bouvard in 1889. He recorded mine workings in schists which were probably excavated for iron ore. Latter it was Bosworth Smith, Engineer for the Deccan Gold Field Development Company Limited who first reported in 1906 that the workings at Thinthini were opened for copper. C. Mahadevan (1941) of the Hyderabad Geological Survey gave an account of geology and mineralisation at Thinthini, where he observed patches of schists of mainly diabase mineralised with pyrite, chalcopyrite and traces of arsenopyrite. S. K. Ramaswamy and others (1967) of the Geological Survey of India carried out geochemical exploration of the property. M. Krishnamurthy (1973) of the Geological Survey of India has given an account of the geology of the area and reported that the ore shoot shows eastward pitch and assay value of samples drawn from the dumps ranged from 0.62 % to 0.99 % Cu.

Subsequently surface exploration for copper in the Thinthini area by trenching and drilling was carried out by the Dept. of Mines & Geology, Govt of Karnataka, during the period 1969-73. Two blocks i.e. eastern block and the western block were explored by drilling followed by some preliminary exploratory mining in the eastern block. Radhakrishna and Sundara Rajan (1972) have given a brief account of the diamond drilling exploration carried out by the department during which 15 boreholes were drilled ranging in depth from 55 to 273 m, totalling 1550 m core drilling over a strike length of 750 m. Since, 1972 eleven more bore holes have been drilled, of these six drill holes fall on the western block of the mineralized zone, which have intersected a narrow zone of mineralization within diabase at the hanging wall contact with pink porphyritic granite. The granite also shows mineralization in the form of disseminations over an average width of 19 m. All the drill holes intersected the east-west trending dyke showing mineralisation over widths ranging from 4.5 m to 15 m with an average grade of 0.8 % Cu. The ore reserves proved by drilling carried out by the Department of Mines & Geology is estimated at about 3 million tonnes averaging 0.8% copper over a strike length of 1000 metres and worked to a depth of 120 m. The width of mineralisation varies between 4 to 11 metres with an average width of 7 metres. However, mineralisation is expected to continue beyond this depth.

Exploratory Mining carried out by M/s HGML

The project was handed over to the Hutti Gold Mines Co Ltd. (HGML) for detailed exploratory mining on 01.04.1974 under the instructions from the Govt. of Karnataka. HGML has carried out exploratory mining for copper between 01.04.1974 to 01.02.1979.

Immediately, after taking over the project, HGML carried out open pit operations for producing 40 metric tonnes of ore per day to meet the requirements of the Pilot Plant. The tonnage of ore extracted from the open-pit mining during the year ending 31st March, 1975 produced about 900 tonnes of fresh ore and 566 tonnes of oxidised ore along with 35,000 tonnes of overburden, which was removed from the site.

The Pilot Plant was commissioned towards the end of February, 1975. The ore fed to the Pilot Plant from the open-pit mine did not show more than 0.25% Cu. This was because the rich portion of the mineralised hanging wall was excavated by ancient mining and a bench had to be opened well in the footwall of the mineralised ore body. Besides, the depth of oxidation was found to go upto 6 to 8 metres from surface. Hence, it was decided to switch over to underground workings.

Underground development was started in May 1975. Exploratory mining was carried out by shaft sinking by development of 3rd and 4th levels in the eastern block of Thinthini. Three shafts, i.e. Winze 'A', No: 1 & 2 shafts were sunk at an interval of 90, 200 m respectively on the ore body and in total 4 levels were developed at 18, 48, 78 & 108 m. A total of 917 m of exploratory development (driving & cross cutting) and 143 m of shaft sinking work was carried out.

Shaft Winze 'A' (located at about 50 m east of western limit of the ore body) and Shaft No. 1 which is about 90 m apart along the strike are connected by 1st level (at about 18 m below surface). Shaft No: 1 and Shaft No: 2 which are 200 m apart could not be connected and a gap of 110 metres was left undeveloped in the 1st level horizon because of the presence of old workings.

Shafts No. 1 and No. 2 and Shaft Winze 'A' were further sunk to 2nd level (30 m below 1st level) and development in 2nd level was initiated. 519 m of development was done through Shaft No. 1 and Shaft Winze 'A' and were interconnected and 112 m of development through Shaft No. 2 was also done. A gap of about 70 m is left for connecting upto Shaft No. 1 Drive.

A total of 917 m of development (driving and cross-cutting) and a total of about 143 m of shaft sinking were carried out as on 26th Oct 1976. A total of 21,566 tonnes of ore with an average grade of 0.44% Cu have been produced by underground development and treated. The total copper concentrate produced were about 2,07,390 tonnes with an average grade of 0.73% Cu.

Due to 50% reduction of mine feed grade of 0.44% Cu, which is less than the cut off grade of 0.60% Cu against the proved ore reserve of 3 m of 0.8% Cu by surface drilling of the Department of Mines & Geology, Govt. Karnataka, the management of HGML took a decision for discontinuation of mining operations at Thinthini Copper Mine with effect from 1979.

M/s. HGML has suspended the mining activities due to non-viability of the project and closed the operations on 01.02.1979. Subsequently, M/s. HGML has carried out afforestation with the help of Forest Dept & converted it into Thinthini Afforestation Project.

Exploration by AMD

Subsequently, Atomic Minerals Division (AMD), Govt of India has carried out preliminary reconnaissance of radiometric survey in and around the Thinthini Copper Project in the year 1998 and this indicated the

SL No	Bore hole No' s:	Run in Metres		Ore zone width in metres	Grade % Cu
		From	To		
1	TTN - 1	57.20	62.20	5.00	0.33
2	TTN - 2	103.85	107.45	3.60	0.62
3	TTN - 3	30.60	35.00	4.40	0.36
4	TTN - 4	34.50	38.50	4.00	0.29
5	TTN - 5	93.35	95.15	1.80	0.16
		96.95	99.30	2.35	0.22
		114.50	116.05	1.55	0.51
6	TTN - 6	26.00	27.60	1.60	0.17
		41.60	42.60	1.00	0.16
7	TTN - 7	51.65	57.15	5.50	0.18
		61.10	63.35	2.25	0.26
8	TTN - 8	25.75	35.75	10.00	0.12
9	TTN - 9	110.00	111.30	1.30	0.29
10	TTN - 10	37.40	39.40	2.00	0.20
		60.20	62.60	2.40	0.86
11	TTN - 11	97.50	98.30	0.80	0.74
		116.00	116.75	0.75	0.22
12	TTN - 12	23.00	28.00	5.00	0.04
13	TTN - 13	42.00	46.00	4.00	0.06
14	TTN - 14	162.00	167.70	5.70	0.05
15	TTN - 15	49.10	61.90	12.80	0.04
Average				5.19 m	0.20% Cu.

presence of Uranium mineralization. The Atomic Mineral Division (AMD), Bangalore has carried out surface diamond drilling (4,800 m, Aug - 2009 to May - 2010) to understand the strike and depth persistence of uranium mineralisation and they drilled 15 boreholes over a strike extension of 700 m with a depth intersection ranging from 95 m to 242.5 m and found that the results were not encouraging.

The said drilling had also intersected copper mineralization at different depths, which were analysed for copper and the details of individual boreholes are as follows:

Based on the cited drilling exploration data of Atomic Mineral Division (AMD), the ore reserve and grade assessed for copper is as follows

Ore Reserve = Strike length (m) X Width (m) X Height (m) X Sp. Gr.
= 700 X 5.19 X 160 X 2.83
= 16,45,0222 tonnes at 0.20% Cu
= 1.64 Million tonnes at 0.20% Cu

The evaluation of the exploration results indicates that, the average grade of copper mineralisation is 0.20% Cu, which is less than the cut-off grade i.e. 0.60% Cu.

In the present economics a minimum grade required to start an underground mine is 0.60% Cu, with considerable width of the ore body. So, 1.64 million tonnes of copper ore in Thinthini area, with average width of the ore body being 5.19 m, having a very low grade of 0.20% Cu, is not becoming economically feasible at the present cost of production. Thus the total project being carried out as an exhaustive scientific venture for proving it as a deposit by consuming both money and time has given a direction of establishing Environmental Eco system in form of Bio-Fuel park.

Bio–Fuel Park

The Karnataka State Bio-fuel Development Board (KSBDB) Govt. of Karnataka, has been established to carry out bio-fuel development activities across the State of Karnataka. KSBDB has initiated action to establish information-cell centres in each of the districts of the state for setting up of Bio-Fuel parks and other similar activities related to development of bio-fuels.

One of the Bio-Fuel parks set up at Madenur in Hassan district, under the jurisdiction of University of Agriculture Sciences (UAS), Bangalore, holds a unique status in the country.

The Thinthini Bio-Fuel Park is the second of its kind in Karnataka State and will be first in North Karnataka. It will be a hub for all the KSBDB activities, where the project has a vision to help the north Karnataka farmers and general public as a whole through research by Agriculture University and a Bio-Fuel information centre.

Accordingly, the area under the ownership of the M/s. HGML was leased to the University of Agricultural Sciences, Raichur for a period of 30 years as per the approval from Board in its 364th meeting held on 28th April, 2013 and subsequently a resolution was ratified in the Board Meeting held on 05.08.2013 in the presence of Vice-Chancellor, UAS, Raichur and Managing Director, HGML, by signing a tripartite agreement between HGML, KSBDB & UAS, Raichur. The main stand of the company (i.e. HGML) is that it will support to the commencement of the setting up of a Bio-fuel Park in the Hyderabad-Karnataka region at Thinthini, by collaborating with the governmental agencies like Agricultural Sciences, Raichur and the exploration of natural resources, this gesture of the HGML could be seen as a promoter of ecology and environment protection.

DISCUSSION

Copper mining in Thinthini is known from the ancient times.

The abject dependence of our country on outside sources for its requirements of copper has emphasized the need for exploring our known occurrences and bringing such promising ones to a stage of production.

The Thintini Copper Project being occurring in the industrially backward area of Yadgiri district, Karnataka, the prognostic attempt for its exploration/ exploratory mining work should not be abandoned half way; hence, it is planned to carry out a detailed exploration for the mining feasibility studies.

Therefore conversion of this mineral project to an ideal Environmental program remains as the need of the time

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Note: Views expressed in this paper are not necessarily those of organization in which the author is working.

BIBLIOGRAPHY

Krishnamurthy, M. (1963) A note on the copper mineralization in Thithini Area, Yadgiri District, Geological Survey of India, Report on investigation.

Krishnamurthy, M. (1971) Copper mineralization in Thithini Area, Yadgiri District, Karnataka State, Geological Survey of India, Miscellaneous Publication.

Mahadevan, C. (1941) Geology of the South and S.W. Parts of Surapur taluk of Yadgiri District. Journal of Hyderabad Geological Survey, Vol. IV, Pt. 1, pp. 110-111.

Mahadevan, C. (1942) Geology of Gulbarga District, Records, Hyderbad Geological Survey, Vol. V, Pt. I.

Menon, A. G. (1979) Sulphur isotope and trace element studies on Sulphide Deposits of Dharwar Craton, Unpubl. Ph. D. thesis, Indian Institute of Science, Bangalore.

Menon, A. G, Venkatasubramanium, V S and Anantha Iyer G V. (1983) Mineralizing environment in Sulphide Deposits of the Dharwar Craton, In: Precambrian of South India. Mem. No 4, Geol. Soc. India (Eds). S. Naqvi and J. J. W. Rogers, Bangalore, pp. 237- 242.

Nagaraja, A. and Virendrababu, P. (1972) Beneficiation of low grade copper ore from Thithini, Karnataka. Report of investigation of Indian Bureau of Mines, Nagpur. IBM/RI. No. 195.

Prabhakar, B. C., Pathan, A. M. and Naganna, C. (1986) Study of opaque minerals from Thinthini, Gulbarga district, Karnataka. Ind. Min. Vol. 27, pp. 154-159.

Prabhakar, B. C., Pathan, A. M. and Naganna, C. (1986) Mineragraphy, geochemistry and genesis of sulphides from Thinthini, Yadgiri district, Karnataka State, India. Proceedings Volume of the Vth Ind. Geol. Congress, pp. 173-179.

Prabhakar, B. C., Pathan, A. M. and Naganna, C. (1987) Geochemistry and petrogenesis of amphibolites from Thinthini, Yadgiri district, Karnataka. Ind. Jour. Earth Sci. Vol. 14, pp. 45-52.

Prabhakar, B. C. and Venkateswara Rao, R. (1991) Floatation of low grade copper ores from Thinthini, Yadgiri district, Karnataka. Proceedings Volume of the 3rd International seminar on Beneficiation and Agglomeration–ISBA, pp. 564-569.

Radhakrishna, B. P. (1967) Copper in Karnataka state, Dept of Mines & Geology Publication.

Ramaswamy, S. K., Gopalakrishna, K. and Vishwanathan, L. S. (1966-1967) Geological Survey of India, Report of Investigation for the field season 1966 - 1967.

Sangurmath Prabhakar, 2005, Geology and Gold mineralization of the Buddinni Gold Deposit, Hutti-Maski greenstone belt, Karnataka. Jour. Geol.Soc. India, Vol. 66, No. 5, 552 – 560.

Sangurmath Prabhakar, 2003, Detailed exploration for Epigenetic Gold Deposit: A Case History: Hira-Buddinni Gold Deposit. Hutti-Maski schist belt, India. Mining in the 21st Century Quo Vadis? Eds: Ghose, A K & Bose, L K, 19th WMC, New Delhi, pp. 315-329.

Sangurmath Prabhakar, 1996, Status of Gold Exploration Hot spots in Hutti-Maski Greenstone belt, Karnataka, India. Gold Resources of India, NGRI, Hyderabad, pp 53-59.

Sangurmath Prabhakar, 2014, Gold Exploration & Mining Scenario in India. 5th AMC, Kolkata, Feb-2014.

Viswanathaiah, M. N. and Krishna Rao, B. (1973) Copper Mineralization at Thintini, Yadgiri Dist, Karnataka. Seminar on Oregenesis and Metallogenesis in the Precambrians of India, Abstract, P. 25.

Vasudev, V. N. (1983) Geological evolution of Archean and Early Proterozoic sulphide deposits of the Dharwar Craton, India. Precambrain of South India; Mem no: 4, Geol. Soc. India, Bangalore, pp 243 – 259.

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SALIENT FEATURES OF GREENSTONE BELTS OF INDIA WITH SPECIAL REFERENCE TO SONAKHAN GREENSTONE BELT, CENTRAL INDIA

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ABSTRACT

The study of greenstone belts and their tectonomagmatic evolution remains one of the focal theme particularly because the major number of gold deposits (with or without nickel) are mostly associated with the greenstone belt. Sonakhan greenstone belt, the area of study, occurs on the north-eastern fringe of Bastar craton in a shape of broad synformal basin with about 40 km length and 30 km width. The mafic meta-volcanics along with sub-ordinate felsic components with intercalations of BIF and chert are formed in a pattern of "island-arc" settings. It extends roughly in NNW-SSE direction displaying two phases of deformations and exhibit green schist to lower amphibolite grade of metamorphism. Gold mineralization is also reported from Sonakhan greenstone belt. The present paper deals with the compilations of fundamental elements of geology of greenstone belts of India and world as a whole and summarizes the conclusions derived from the study carried out by the authors regarding tectonomagmatic evolution and comparison of geo-chemistry of Sonakhan Greenstone Belt.

Keywords: *Greenstone belt, geochemistry, metavolcanics*

Introduction

The ancient and stable cratonic nuclei incorporating the greenstone belts occur as "pod-like" domains of Precambrian rocks that originated on top of a pre-existing basement of granitic and gneissic rocks. These greenstone belts, along with the basement granites and gneisses constitute a substantial part of the shield areas all over the world. The episodes and cycles of volcanism, sedimentation, plutonism, deformation, and metamorphism are all combined to produce a very complex geology for these greenstone belts.

The Precambrian shields on the earth exhibit scattered terrains of metamorphic and magmatic rocks of Archaean age, surrounded or transected by more or less linear belts of Proterozoic rocks. The Archaean terrains are mainly of two types – (1) Supracrustal sequences or greenstone belts, comprised of metamorphosed basaltic and locally ultramafic lava flows, partly of submarine nature, with minor proportions of intermediate and acidic lavas along with associated meta-sedimentary sequence, (2) Gneissic complex of quartzo-felspathic composition (mostly tonalitic in nature) and migmatites are intruded by granitic plutons. Greenstone belts are elongated deformed belts encompassing low to medium grade metamorphic rocks at the base overlain by metasedimentary rocks. They occur as scattered remnants on cratons. A typical greenstone terrain is dominantly composed of metavolcanic component, which is represented by Baghmara Formation in Sonakhan Greenstone Belt.

Condie (1981), in his classic account on Archaean Greenstone Belts, has discussed various aspects of contemporary research done in greenstone terrains all over the world. The salient features of greenstone belts summarized from his work are as follows:-

1. Greenstone belts are linear to irregularly shaped synformal supracrustal successions which range in width from 5 to 250 km and in length up to several hundred kilometres.
2. Most greenstone belts are faulted synforms with major faults running parallel to the synformal axes.
3. Greenstone belts are typically metamorphosed to the greenschist or amphibolite facies and the metamorphic grade may increase near contacts with plutons.
4. Primary textures and structures are preserved to varying degrees in greenstone successions.
5. Greenstone belts are surrounded by granitic terrains which are comprised of gneissic complexes, diapiric-intrusives, batholiths, and late discordant plutons.
6. Greenstone successions are composed chiefly of pillowed mafic volcanic lava. Some Greenstone belts contain an abundance of ultramafic and komatiitic lavas in their lower part.
7. Immatured clastic sediments often dominate in the upper part of Greenstone successions.
8. Two basic types of Greenstone successions are recognized based on volcanic abundances. The bimodal type is composed chiefly of ultramafic and related mafic rocks with minor amounts of chert and felsic volcanics. The calc alkaline type is composed chiefly of mafic to felsic volcanics and derivative clastic sediments.
9. Mature clastic sediments, carbonates and alkali rich volcanic rocks are uncommon in Archaean greenstone successions.
10. Wavelengths and amplitudes of most folds in granite greenstone terrains are small compared to Phanerozoic orogenic belts.
11. Important Nickel, Iron, Gold and base metal deposits occur in the Archaean greenstone belts.

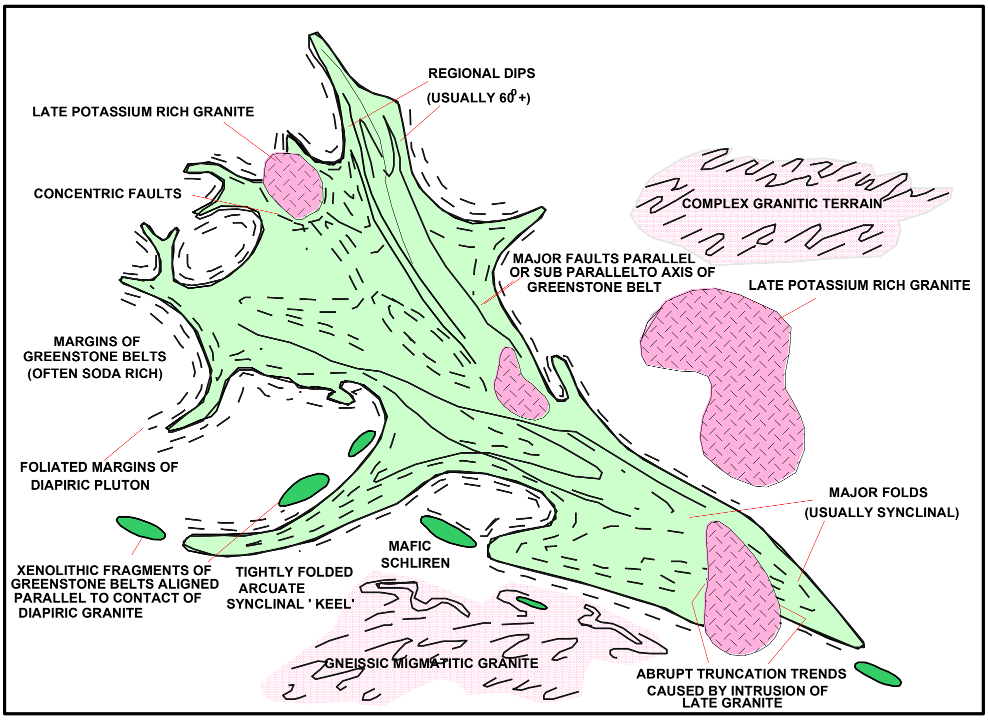

Figure-1: Schematic map of a greenstone belt showing characteristic features (After Anehausser et al., 1969)

An idealized map of a typical greenstone belt showing some of the main features (after Anehausser et al., 1969) is given in Figure-1.

An Overview of the occurrence of Greenstone Belts in Peninsular Indian Shield

The Peninsular Indian Shield is largely composed of Precambrian rocks of diverse tectonic settings. These rocks impart a composite mosaic of the Peninsular Shields, with relics of at least four of Archaean shields, older than 3.0 Ga., e.g. Dharwar, Bastar, Singhbhum and Bundelkhand. Phases of opening and closing of rifts, crustal growth, emplacement of granites, episodes of ensialic magmatism and orogenesis have been recognized around these nuclei. The current understanding of the tectonic set up of the Peninsular Indian Shield suggests that it can be divided into two major crustal provinces i.e. Northern Crustal Province (NCP) and Southern Crustal Province (SCP) and these two are separated by a Meso-proterozoic tectonothermal event which is widely known as Central Indian Tectonic Zone (CITZ) (Ramchandra and Roy, 1998). The NCP consists of Bundelkhand Craton and the SCP comprises Dharwar Craton, Singhbhum Craton and Bastar Craton.

The Bundelkhand Craton comprises enclaves of metasedimentary and metavolcanic rocks within multiphase granitoids (Basu, 1986). It occupies about 26,000 sq. km area of northern part of M. P. and southern & southwestern part of U. P. It is believed to have formed during a time span from 3.27 to 2.24 Ga (Zainuddin and Mondal, 1998). Towards the south and the west, younger sequences of Bijawar, Gwalior and Vindhyan Supergroup rocks overlie the granitic complex and in the north and east, it remains covered under the Indo-Gangetic alluvial plane (Sharma, 1988).

The Dharwar Craton covers an area of about 2,36,000 sq. km in Karnataka and adjoining Andhra Pradesh. It is bordered by the Arabian Sea in the west and high grade granulite terrain of Tamil Nadu-Kerala in the south. The northern extension of this craton is hidden under the Deccan Trap. The proterozoic basins of Cuddapah, Kaladgi and Bhima cover a part of gneissic rocks of Dharwar craton towards the east and north east (Radhakrishna, 1983). The Dharwar Craton is divisible into a western and an eastern block, separated by Chitradurga Boundary Fault (Ramakrishnan, 1976). The western Dharwar Craton mainly constitutes the Peninsular Gneiss, Dharwar Supergroup, Sargur Group and Closepet Granite; whereas the eastern part of Dharwar Craton comprises of Kolar, Hutti, Ramgiri, Gadag and Sandur Greenstone Belts. Mafic and ultramafic metavolcanics are dominant in these supracrustal belts (Mukhopadhyay & Shrinivasan, 2003). The granite gneiss of the western block contain huge supracrustal belts of Dharwar Supergroup rocks, which shows low grade metamorphism but the enclaves and narrow coherent belts of Surgur Group have undergone high grade metamorphism.
The Singhbhum Craton is bounded by the arcuate Singhbhum Shear Zone and southerly lying Sukinda Thrust Zone. The major lithological assemblages occurring in the Singhbhum Craton include Singhbhum Granite along with the rocks belonging to Iron Ore Group, Singhbhum Supergroup and Older Metamorphic Group. The early Archaean Older Metamorphic Group constitutes the oldest greenstone succession in the Singhbhum Craton and it witnessed a phases of emplacement of granites and tonalities during 3400 Ma (Singh, 1998).

The ENE-WSW trending CITZ represents a belt of collaged terrains broadly corresponding to the Satpura Mobile Belt. The CITZ has two parallel structural units of unequal width. Its narrow northern belt represents the early Palaeo-Proterozoic

Mahakoshal Rift Zone which is confined between two deep seated faults of Son-Narmada Lineament. The wider southern belt of the CITZ in the central sector is represented by the Meso-Proterozoic Sausar Mobile Belt. The Chhotanagpur Granite Gneiss Complex and the Singhbhum Mobile Belt (Posiibly equivalent to Gangpur Group) represent the CITZ in the eastern sector. The Bastar Craton is bounded to its southwest by the Pranhita-Godavari Graben and in the northeast by Mahanadi Graben. The Eastern Ghats Mobile Belt occurs along its southeastern border and CIS forms its northwest border. The Bastar Craton includes older gneiss-supracrustal association, younger supracrustals, mobile belts and platformal cover. The older supracrustals are intervaded by gneissic components (> 3.0 Ga in age) and are widely dispersed with large mappable metamorphic complexes, which shows polyphase deformations. Younger supracrustals (neo-Archaean to palaeo-Proterozoic in age) include Kotri-Dongargarh and Sonakhan Supracrustals. They occur as large linear belts having unconformable contact with older supracrustals and include volcano-sedimentary sequences and granitic components (Ramchandra et al., 2001). The part of the SCP including the Bastar Craton was earlier referred to as the Bhandara Craton (Naqvi and Rogers, 1987) or Deccan Protocontinent (Yedekar et al., 1990) or as Central Indian Craton (Ramakrishnan, 1990). Figure-2 illustrating tectono-stratigraphic history of the Peninsular Indian Shield gives a broad idea about the spacio-temporal distribution of various lithotectonic associations of the Peninsular Indian Shield.

Regional Geology of Sonakhan Greenstone Belt

The Palaeo-proterozoic litho-assemblage of Sonakhan Greenstone Belt (located at the northern fringe of Bastar craton) are formed on the margins of the cratonic nucleus, where granite gneisses are associated with linear to oblong volcano-sedimentary sequence of ensimatic nature. These ensimatic supracrustals have been characterized as “Greenstone Belts” whose colour is due to abundance of one or more of the green minerals like chlorite, epidote and actinolite. They preserve several pristine characteristics of the igneous and sedimentary components, which suffers through low grade metamorphism. The granitoids are plutonic in nature, while the volcano-sedimentary sequences have evolved in shallow depths and are, therefore, often called the “Supracrustals”. These supracrustals generally exhibit greenschist to lower amphibolite facies of metamorphism.

The Sonakhan Greenstone Belt (SGB) exposes a volcano-sedimentary sequence in the northeastern part of Raipur district. It is in unconformable and/or tectonic contact with Baya gneissic complex. (Ramchandra et al, 2001). The SGB shows a NW-SE trend and is disposed almost perpendicularly to the NE-SW trending Central Indian Tectonic Zone (CITZ). The Sonakhan Greenstone Belt is surrounded by the Chhattisgarh Supergroup and the younger granitoids of Bastar Craton imparting an inlier structure (Figure 2.3).

Das et al. (1990) described the distribution of main lithological components of the belt and presented an updated stratigraphic succession of the area on the basis of studies of primary igneous and sedimentary criteria in well exposed sections along with detailed structural fabrics. They classified the lithounits of Sonakhan Belt into Sonakhan Group and Bilari Group. They further sub-classified Sonakhan Group into Baghmara Formation and Arjuni Formation on the basis of younging criteria, unconformity and relative abundance of igneous and sedimentary litho-components. Saha et al. (1998) studied the structural relationship between the Baya Gneissic Complex and the

Sonakhan Group. The geological map of Sonakhan Greenstone Belt has been presented in Figure-3 and the litho-stratigraphic succession of the Sonakhan Greenstone Belt proposed by Nitish Das et al., (1990) has been given in Table 1

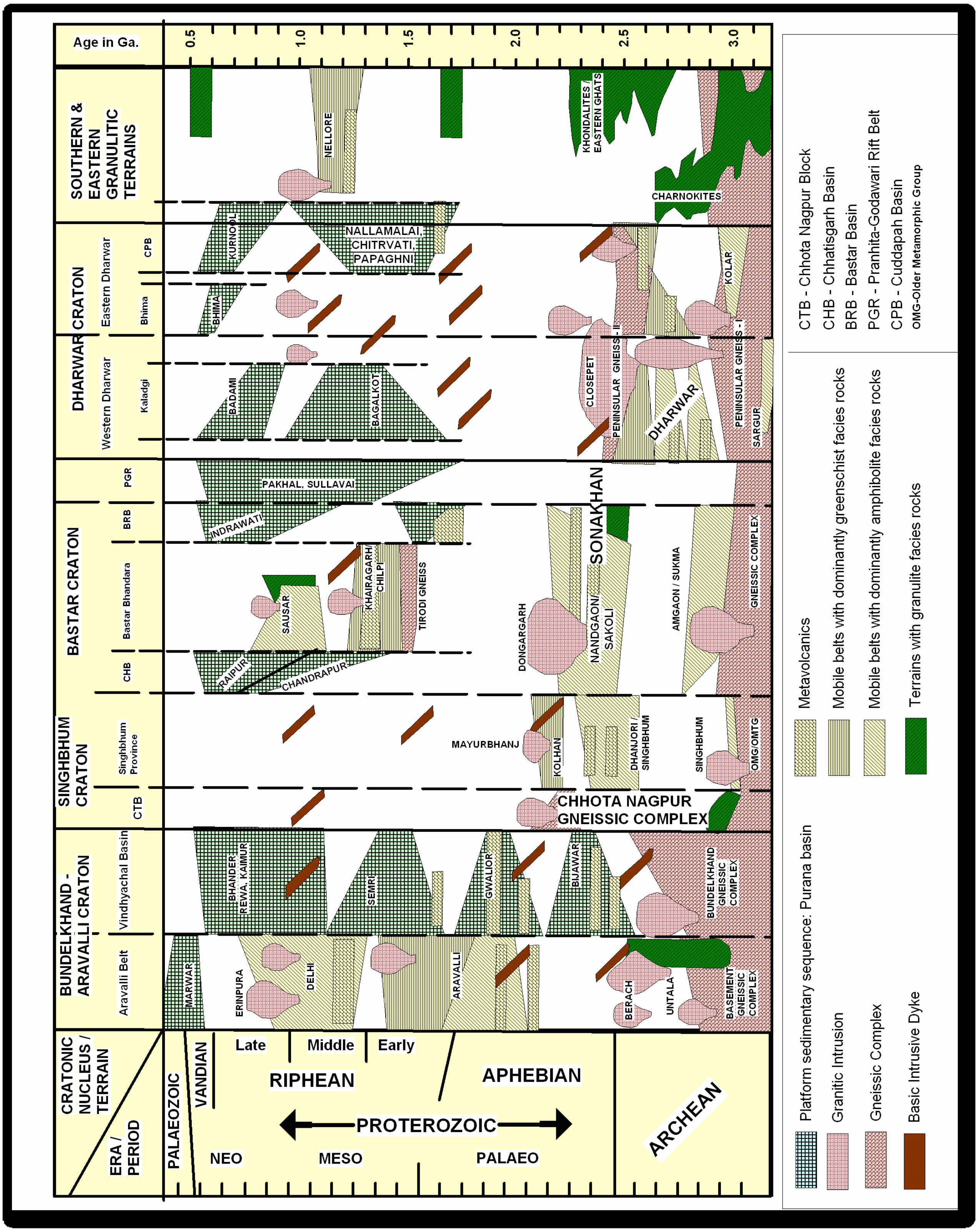

Figure 2 : Spacio-temporal distribution of various litho-tectonic associations of Peninsular Indian Shield (modified after Kale,2016)

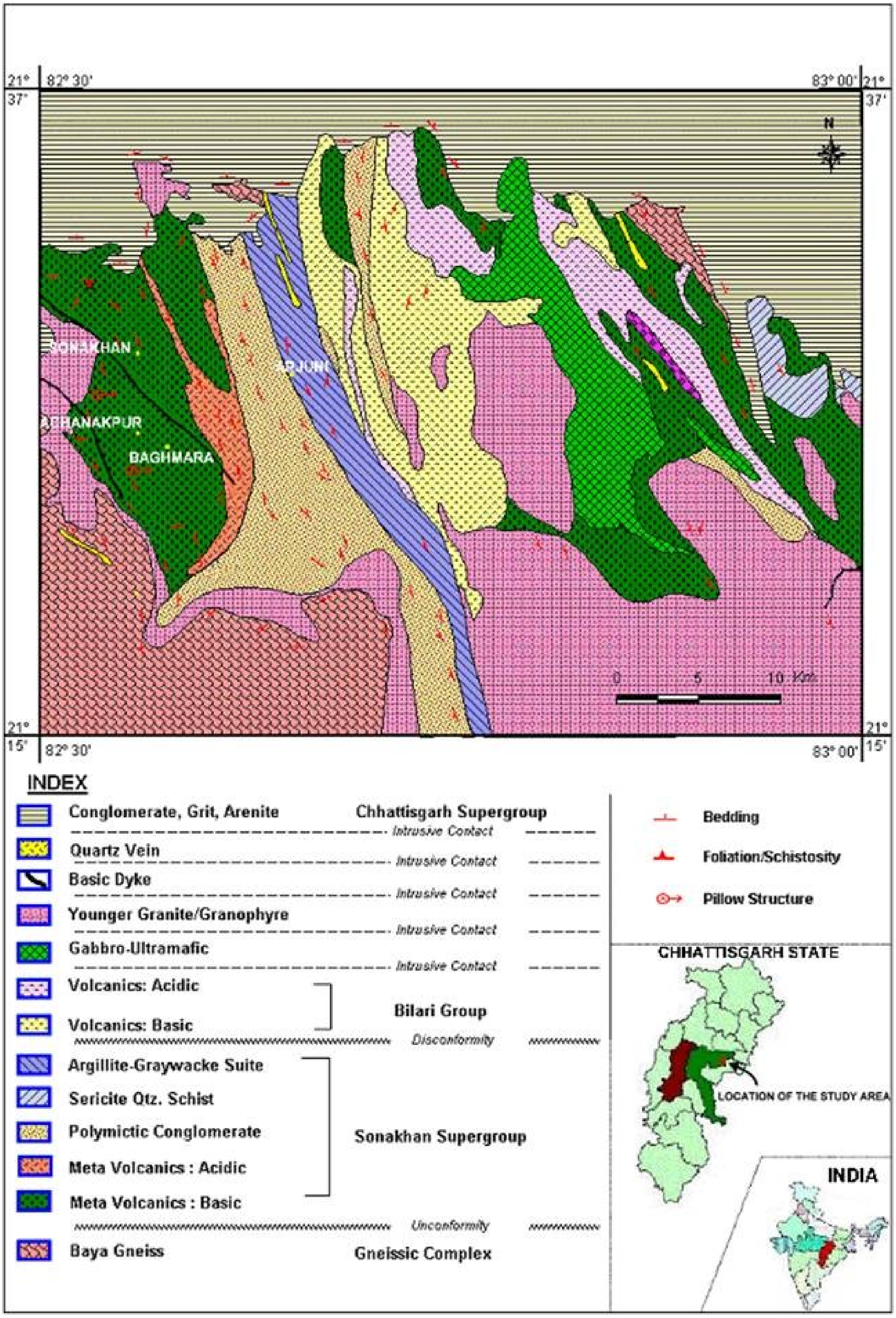

Figure-3: Geological map of Sonakhan Greenstone Belt (modified after Das et al, 1990)

Table-1: Litho-stratigraphic Succession of Sonakhan Greenstone Belt after Das et al., (1990)

Chhattisgarh Super Group		Conglomerate, grit, arenite, limestone
Unconformity		
Basic Dykes		Quartz vein, dolerite, gabbro
Intrusive Contact		
Granitoids		Pegmatite, aplite, granophyre and porphyritic granite
Intrusive Contact		
	Ultramafic Intrusive	
Intrusive Contact		
Bilari Group	Lakhdabri Acid Igneous suite Arangi Basic Igneous suite	
Unconformity		
Sonakhan Group	Arjuni Formation	Metamorphosed polymictic conglomerate, graywacke, argillite, B.H.J., arenite with thin band of basic volcanics.
	Unconformity	
	Baghmara Formation	Metaultramafics, tremolite actinolite schist, amphibolite metabasalt, pillowed metabasalt, pyroclastics, acid volcanics and tuffs BIF, chert etc.
Unconformity		
Baya Gneiss Complex Gneisses :		Tonalitic and granodioritic gneiss migmatites and granites with restites of BHQ, metaultramafite, mica schist, quartzite etc.

Lithological Description

Baghmara Formation: The Baghmara Formation forms basal unit of Sonakhan Group and it occupies most of the hilly terrains and is best developed in and around village Baghmara. It comprises a suite of bimodal volcanics in association with pyroclastics, B.I.F., cherts and fine grained clastics. The Baghmara Formation extends from Sonakhan village in the North up to Baya in the South. In the southwestern and southeastern part, the Baghmara Formation wraps around granite and along the contact of metabasalts and granite, exposures of Tremolite-Actinolite Schist and Talc-Tremolite Schist are observed.

The ultramafic component of Baghmara Formation is represented by Talc-Tremolite Schist and Tremolite-Actinolite Schist. They occur as small pockets in the study area, confined mainly to western and southwestern margin of hilly terrain. Their colour varies from various shades of green to buff colour and they exhibit schistosity trending parallel to the regional trend i.e. NNW-SSE. The outcrops of Tremolite-Actinolite Schist observed near Amaruva and Rangora village are mostly weathered.

The mafic volcanics, comprising fine grained metabasalts, exhibit features like pillow structures and vesicular structures. The vesicles are filled up with secondary minerals like quartz, calcite, epidote etc. The pillows occur in clusters. They are well developed in Jungle Pahar, Deodhara spring, Devgarh ghat section, Achnakpur and Baghmara localities. The size of the pillows ranges from about 10 cm to 60 cm along their longer diameter and shows radiating cracks from the centre towards periphery. The triangular voids among pillow margins are occupied by epidote, carbonate, quartz etc. The 'V' of pillow margins gives an idea about the younging direction of the sequence. At some places pillows are also deformed. Near Dongipani, the spectacular overturning of pillows was observed indicating first phase of deformation. Presence of pillows signifies sub-aqueous environment of volcanism, it changes to sub aerial environment as indicated by vesicular and amygdaloidal structures. The fine grained meta-basalts grade into schistose amphibolites near Devpur. The metabasalts are traversed occasionally by intrusives of gabbro, dolerite, younger granite and quartz porphyries.

The pillow lavas have suffered hydrothermal alteration represented by intense silicification, sericitization, chloritization and sausseritization similar to that of Hutti-Maski belt (Venkatesh, 2001). Numerous quartz veins of variable width ranging from few centimetres up to 3 metres are frequently seen intruded in the metavolcanics. These veins follow major shear trend (NNW-SSE) exhibiting sheared to brecciated zone (Mishra, 1996). The milky-white quartz veins and smoky quartz veins form favorable locales for sulphide minerals (such as arsenopyrite and galena) and gold mineralization in the area.

The acid volcanics comprising mainly rhyolites and altered tuffs occur adjacent to the metabasalts and show a gradational contact with them. They occur as hillocks near Runjhuni, Thelkadabri, southwest of Rajadeori and around Golajhar and Mahakam. They extend from Dumarpali in the South and reach their maximum thickness in the west of Raja Deori and towards further north, it branches into two zones. One zone extends up to the west of Sonakhan and another up to south of Kasaundi. The rhyolites are porphyritic to schistose in nature and are greenish gray to pink in colour. The acid tuff occurs as pockets and lenses, within the acid volcanics and it is often kaolinized.

The Baghmara Formation is at places interspersed with layers of ferruginous sulphide bearing chert. These chert bands extend discontinuously with varying thicknesses. Exposures of B.I.F. and such ferruginous sulphide bearing chert are found near Devgaon, Bhusripali and Sonakhan.

Thin lenses of euxinic shale composed of carbonaceous argillittic matter are also found in association with pyroclastic rocks near Bhusripali, which possibly indicates the brief pause in volcanism.

Structure

The Sonakhan Greenstone Belt represents a broad syn-formal basin with moderate plunge to the north-northwest and closure to the south near Baya (Das et al., 1990). Two phases of deformation have been observed in the Sonakhan Greenstone Belt. The first phase is represented by (F_1) folds, best developed in B.I.F. and chert bands. These are mostly tight and steeply inclined to upright folds with their axial surface running parallel to the regional trend i.e. NNW-SSE. They show moderate to steep plunge towards NNW. The repetition of various lithounits of SGB is the result of F_1 folds. The second phase of deformation is represented by broad and open flexures (F_2) folds having NE-SW trending axial planes. They have developed variable plunge on the S_1 surface due to superimposed folding.

The planar structures in the area include primary stratification plane (S_0) in B.I.F. and chert bands and flow layers of metabasalts. The (S_1) schistosity plane has developed in schistose rocks due to parallel arrangement of chlorite and actinolite grains and the meta-basalts. The other planar structures include those developed due to flattening and preferred orientation of pillows in metabasalts. Generally a westerly dip ranging from 65° to 82° was observed along the foliation planes.

The linear structures in the area include pebble orientation in Jonk Conglomerate developed due to parallel arrangement of stretched pebbles, fold axis lineation of microfolds and intersection lineation developed by S_1 on S_0 plane.

The major trend of the lineaments like faults and shear zone in the Sonakhan Greenstone Belt generally extends in NNW-SSE direction. The Jonk River forms the most prominent drainage in the study area, which possibly follows such lineaments.

Comparative Stratigraphy and Geochemistry of Greenstone Belts

The geochemistry of mafic metavolcanics of Baghmara Formation has been compared with that of other greenstone belts of the world in Table-2.

Hutti Greenstone Belt, located in the eastern sub-block of Dharwar Craton comprising meta-volcanic rocks of predominantly tholeiitic composition with sub-ordinate proportion of felsic meta-volcanics and Banded Iron Formation has been studied by various workers (Biswas, 1990; Sangurmath, 1990; Riyaz Ulla et al., 1997; Giritharan and Rajamani, 1998; Pal and Mishra, 2002). Salient features of Sonakhan Greenstone Belts and Hutti Greenstone Belt are compared in Table-3 and their geochemical features have been compared in Table-4.

Table-2: Comparision of geochemistry of mafic metavolcanics of Baghmara Formation , Sonakahn Greenstone Belt with other well documented Greenstone Belts.

Parameter	Pilbara (Av. of 91 samples)	Yilgarn (Av. of 36 samples)	Barberton (Av. of 16 samples)	Baghmara Formation (Av. Of 11 samples)
SiO_2%	49.63	51.04	50.6	52.717
TiO_2%	1.33	0.92	1.04	0.796
Al_2O_3%	13.41	15.22	13.7	13.275
$Fe_2O_3^t$%	12.46	10.44	11.87	12.095
MnO%	0.22	0.23	0.21	0.174
MgO%	5.98	6.44	6.3	6.769
CaO%	9.97	11.19	9.26	10.45
Na_2O%	2.14	2.55	2.52	1.478
K_2O%	0.3	0.15	0.31	0.316
P_2O_5%	0.13	0.13	0.1	0.086
Sum	95.57	98.31	95.91	98.156
Mg No.	46	52	49	49.88
V ppm	329	313	209	239.3387
Cr ppm	159	346	161	180.1398
Ni ppm	70	149	122	76.52
Rb ppm	10	8	7	8.8503
Sr ppm	138	111	180	112.5834
Ba	90	114	56	68.4628
Ni/Cr	0.44	0.48	0.76	0.42
Cr/V	0.48	1.14	0.77	0.75

Table-3: Comparison of salient features of Hutti Greenstone Belt and Sonakhan Greenstone Belt

S.No.	Salient Features	Hutti Greenstone Belt	Sonakhan Greenstone Belt
1.	Location	Eastern sub-block of Dharwar Craton	North eastern fringe of Bastar Craton
2.	General trend	NNW – SSE	NNW - SSE
3.	Overall Structure	Hook shape	Broad synformal basin
4.	Dominent lithology	Mafic meta-volcanics with subordinate felsic meta-volcanics along with intercalations of BIF and Chert	Mafic meta-volcanics with subordinate felsic meta-volcanics along with intercalations of BIF and Chert
5.	Age	~ 2600 Ma	~ 2500 Ma (Ghosh et al., 1995)
6.	Aerial extent	65 km length 8 km width	40 km length 30 km width
7.	Deformation	Three phases of deformation	Two phases of deformation
8.	Tectonic setting	Island arc setting	Island arc setting
9.	Metomorphism	Greenschist to lower amphibolite transitional facies	Greenschist to lower amphibolite transitional facies
10.	Environment of emplacement of mafic meta-volcanics	Submarine (as indicated by presence of pillows)	Submarine (as indicated by presence of pillows)
11.	Hydrothermal alteration	Present	Present
12.	Metallogeny	Well known for gold mineralization	Gold mineralization present

Table-4: Comparison of Geochemistry of mafic metavolcanics of Hutti Greenstone Belt and mafic metavolcanics of Baghmara Formation.

Parameter	Mafic metavolcanics of Hutti Greenstone Belt (Av. of 16 samples)*	Mafic metavolcanics of Baghmara Formation (Av. of 11 samples)
SiO_2	48.669	52.717
TiO_2	1.068	0.796
Al_2O_3	14.15	13.275
Fe_2O_3	12.031	12.095
MnO	0.188	0.174
MgO	7.233	6.769
CaO	10.507	10.45
Na_2O	1.86	1.478
K_2O	0.294	0.316
P_2O_5	NA	0.086
Sum	98.507	98.156
Mg No.	53.06	49.88
Cr	288.188	180.140
Ni	164.125	76.52
Y	21.556	18.338
Zr	64.313	17.746
Nb	2.333	1.334
Ni/Cr	0.569	0.42
CaO/Al_2O_3	0.743	0.787

Salient Observations

1. The Baghmara Formation forms the prominent metavolcanic component of Sonakhan Greenstone Belt. It is a late Archaean-Palaeo proterozoic Greenstone Belt of Central India, showing NNW-SSE trend.
2. The overall geological milieu of Baghmara Formation suggests submarine environment of the basin.
3. The presence of mineral assemblage (i.e. pyroxene + plagioclase+ chlorite + actinolite + opaques) indicates greenschist facies of metamorphism.
4. Petrographic studies revealed presence of spinifex texture, thus indicating a komatiitic affinity for the basalts along with other textures like pillotaxitic, variolitic type, common in tholeiitic basalts.
5. Study of major and trace element geochemistry of the basin indicates bimodal suite of volcanism.
6. Finally, the conspicuous absence of clastic components in iron and silica bands of BIF intercalated with mafic metavolcanics of Baghmara Formation indicates that the deposition took place by chemical precipitation due to fluctuation in Eh and Ph values of the sea water. The intimate association of volcanic rocks and BIF indicating possible genetic relation between them, points towards submarine volcanic exhalation and/ or leaching of the sea floor basalt similar to the mechanisms of formation of Algoma type BIF occurrences associated with the volcanism in the form of "Island-arc" setting.

So the overall geological and geochemical characteristics along with the complex deformational history and presence of auriferous quartz veins suggest that the Sonakhan Greenstone Belt resembles the other well-documented Archaean greenstone belts of India and that of the world.

Acknowledgements

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REFERENCES

Anehausser, C. R., Mason, R., Viljoen, M. J. and Viljoen, R. P. (1969) Reappraisal of some aspects of Precambrian shield geology. Geol.Soc. Amer. Bull., v. 80, pp. 2175-2200.

Basu, A. K. (1986) Geology of Bundelkhand Granite massif, Central India. Rec. Geol Surv. Ind., 101, pp 61-124.

Biswas, S. K. (1990) Gold Mineralization in Hutti Maski Greenstone Belt,Karnataka, India. Indian Minerals, Vol. 44, Part 1, 1-14.

Condie, K. C. (1981) Archaean Greenstone Belts. Elsevier Scientific Publishing Co., New York, 434p.

Das, N., Royburman, K. J., Vatsa, U. S. and Mahurkar, V. Y. (1990) Sonakhan Schist Belt-A Precambrian granite-greenstone complex. Geol. Surv. India Spl. Pub. No. 28, pp. 118-132.

Giritharan, T. S., Rajamani, V. (1998) Geochemistry of the metavolcanics of the Hutti-Maski Schist Belt, South India: Implications to Gold Metallogeny in the Eastern Dharwar Craton. Jour. Geol. Soc. Ind. v. 53, pp. 577-581.

Glikson, A. Y. and Hickman, A. H. (1981b) Geochemistry of Archaean volcanic successions, eastern Pilbara Block, Western Australia. Aust. Bur. Miner. Resour. Rec. v. 36.

Hallberg, J. A. (1976) A petrochemical study of a portion of the western Yilgarn block. Com. Sci. Indust. Res. Organ. Miner. Res. Lab. Report, No. FP. 13.

Kale (2016) Proterozoic Basins of Peninsular India:Status within the Global Proterozoic Systems. Proc Indian Natn Sci Acad 82 No. 3 July Spl Issue 2016 pp. 461-477.

Mishra, V. K. (1996) Status Report of Gold Deposit of Sonakhan, Raipur, M.P., Report Directorate of Geology and Mining, M. P. pp 196-204. In: Gold'96 held at NGRI, Hyderabad, sem.v. pp 196-204.

Mukhopadhyay, D. and Srinivasan, R. (2003) Evolution of Dharwar Craton. In: Advances in Precambrian in Central India, Eds. Abhinaba Roy and D M Mohabey, Ground Geol. Magz. Spl. V. 7, pp. 1-7.

Naqvi, S. M. and Rogers, J. J. W. (1987) Precambrian Geology of India. Oxford, Oxford University Press, pp. 223.

Pal, N. and Mishra, B. (2002) Alteration geochemistry and fluid inclusion characteristics of the greenstone-hosted gold deposit of Hutti, Eastern Dharwar Craton, India. Mineralium Deposita, 37: 772-736.

Radhakrishna, B. P. (1983) Archaean granite greenstone terrains of South Indian shield. In: Naqvi S. M. and Rogers J. J. W. (Eds.): Precambrian of South India. Geol. Soc. India. Mem. v. 4, pp. 1-46.

Ramachandra, H. M. and Roy A. (1998) Geology of intrusive granitoids with particular reference to Dongargarh granite and their impact on tectonic evolution of the Precambrian in central India, Ind. Min., 52 (1 & 2), pp. 15-33.

Ramchandra, H. M., Roy, A., Mishra, V. P. and Dutta, N. K. (2001) A critical review of the tectonothermal evolution of the Bastar Craton. M.S.Krishnan Cent.Comm. Nat. Sem., Geol. Surv. Ind., Spl. Pub., v. 55, pp. 161-180.

Ramakrishnan, M. (1990) Crustal Development in southern Bastar, Central Indian Craton. Geol. Surv. Ind., Spl. Pub., v. 28. pp 44-66.

Ramakrishnan, M., Viswanatha, M. N., Swaminathan, J. (1976) Basement-cover relationship of Peninsular Gneiss with high-grade schists and greenstone belts of southern Karnataka, Jour. Geol. Soc. India. 17: pp. 97-111.

Riyaz Ulla, M. S., Ahmed, S. A., Pathan, A. M. and Hausen, D. M. (1997) Tectonic environment and petrogenesis of Gold-bearing volcanics of Hutti greenstone belt, Dharwar Craton, India. Indian Minerals, v. 51, No. 1 & 2, pp. 25-40.

Saha, D., Deb, G. K. and Dutta, S. (1998) Granite greenstone relationship in the Sonakhan Belt, Raipur District, Central India. Proceedings Volume. Int. Sem. Precambrian Crust in Eastern and Central India, IGCP-368, Bhubaneshwar.

Sangurmath, P. S. (1990) A study of the geology and gold mineralization at Buddini area of Hutti-Maski greenstone belt, Raichur District, Karnataka, India with special reference to exploration aspects. Unpublished Ph. D. Thesis, Gulbarga University, Gulbarga, 170 pp.

Sharma, K. K. (1998) Geological evolution and crustal growth of the Bundelkhand craton and its relicts in the surrounding regions, North Indian Shield, In The Indian Precambrian, Paliwal, B S Ed., Scientific Publishers, India, 33-43.

Singh, S. P. (1998) Precambrian stratigraphy of Bihar. Paliwal, B.. S edition, The Indian Precambrian. Jodhpur, India. Scientific Publ., p. 376–408.

Singh, S., Sahoo, P. and Venkatesh, A. S. (2006) Geochemistry of mafic volcanic host rocks associated with Gold mineralization within Sonakhan Group, Central India. Indian Journal of Geochemistry, 21(2), pp. 381-400.

Yedekar, D. B., Jain, S. C., Nair, K. K. K. and Dutta, K. K. (1990) Central Indian Collision Suture. Geol. Surv. Ind., Spl. Pub., v. 29, pp. 1-43.

Venkatesh, A. S. (2001) Geochemical signatures and auriferous implications in Sonakhan Greenstone Belt, Chhattisgarh. Geol. Surv. India. Spl. Pub. No.55, pp. 219-228.

Viljoen, M. J. and Viljoen, R. P. (1969) An introduction to the geology of Barberton Granite-Greenstone terrane. Geol. Soc. S. Africa Spec Publ. No. 2, pp. 9-18.

Zainuddin, S. M., Mondal, M. E. A. (1998) Trends of arc maturity in subduction related Bundelkhand batholiths of Central India. In: The Indian Precambrian, B. S. Paliwal Ed., Sci. Pub., Jodhpur India, , pp. 73-80.

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ENIGMATIC DEEPWATER SYSTEM: A BRIEF INTRODUCTION

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ABSTRACT

Deep marine depositional systems have been studied in recent time with availability of more and more geophysical data, mostly seismic data. Deep marine depositional systems are here defined as environments situated beyond the shelf-slope break. In the oil and gas industry Deep water is defined by water depth more than 200 m. Hydrocarbon Exploration and production activities in deep water (200-2000 m) and ultra-deep water (>2000 m) basins have expanded greatly during the past 15 years. Understanding how sediment moves from shelf to deep water is quite crucial in characterizing deep water system. Shelf region of a continental margin acts as a staging area for sediments, which later area dispersed into the deep water. Sedimentation in deep water environment is mostly done by gravity flows of sediments. Gravity flow deposits again can be classified as turbidite or debris flow based on rheological composition. Data from published material as well as open source platforms are used in this study to discuss some of depositional elements in deep water environment .Significant geomorphic features like submarine canyons, channel, levees, sediment waves and mass transport complex are discussed in the paper. Submarine canyons present on the slope region are crucial to understand as the canyons act as conduit for sediment delivery into the deep water system. Submarine canyons are steep sided, straight to sinuous valleys (V or U-Shaped), with negative relief features and incised into the shelf or continental slope, that are formed by erosion of the underlying sediment section. Submarine channels are morphological features that carry sediments from areas of higher topography to lower-lying regions via relatively narrow, elongate pathways with clear margins. Deep water channels are morphologically comparable to fluvial channel systems. Well-developed deep water channels are associated with prominent levees. Over bank deposits are clearly seen in 3D seismic data. Fan shaped bodies deposited in the deep water environments are termed as basin floor fan or slope fan based on the location of the body. Mass transport complex are one of the characterizing features of deep water environment. Mass transport complex deposits resulted from various mass wasting processes like slide, slump, debris flow etc. Sediment waves are wavy seismic signatures looking like sand dunes of deserts, but deposited in deep water environment. Identification of geomorphic features in deep water system could be helpful in understanding sediment dispersal as well as reservoir development.

Introduction

Hydrocarbon Exploration and production activities in deep water (200-2000 m) and ultra-deep water (>2000 m) basins have expanded greatly during the past 15 years. In the present day scenario deepwater exploration has become a major component of the petroleum industry's annual upstream budget. With new cutting edge technology in drilling as well as other aspects of exploration deep water basins have become a prominent target. Technological revolution has expanded the options for exploration of deepwater deposits, as well as slope and basin deposits that were previously beyond the reach of the drill bit in present day deepwater settings. Although a number of prominent oil and gas discoveries have been made in some of the basins around the world, most E & P activities have concentrated in only few areas of the world, namely: the northern Gulf of Mexico, Brazil, and West Africa and a part of Asia. Globally, deep water remains an immature frontier, with many deepwater sedimentary basins being only lightly explored. This paper gives an eagle's view on the deepwater environment. Figure 1 shows important deepwater basins of the world as well as India.

Definition of Deepwater: How deep is deep

Deep marine depositional systems are here defined as environments situated beyond the shelf-slope break. In the oil and gas industry Deep water is defined by water depth more than 200 m. The definitions are different for Geoscientists and driller. As per drilling fraternity deep water is present day water depth more than 200 m. But for Geoscientist deep water means any sediment deposited in the slope and basin region. Deepwater could be marine or lacustrine condition. For this paper we will only be restricted to the deep marine environment only. For clarity in discussion Figure 2 the schematic diagram defining Deepwater is presented.

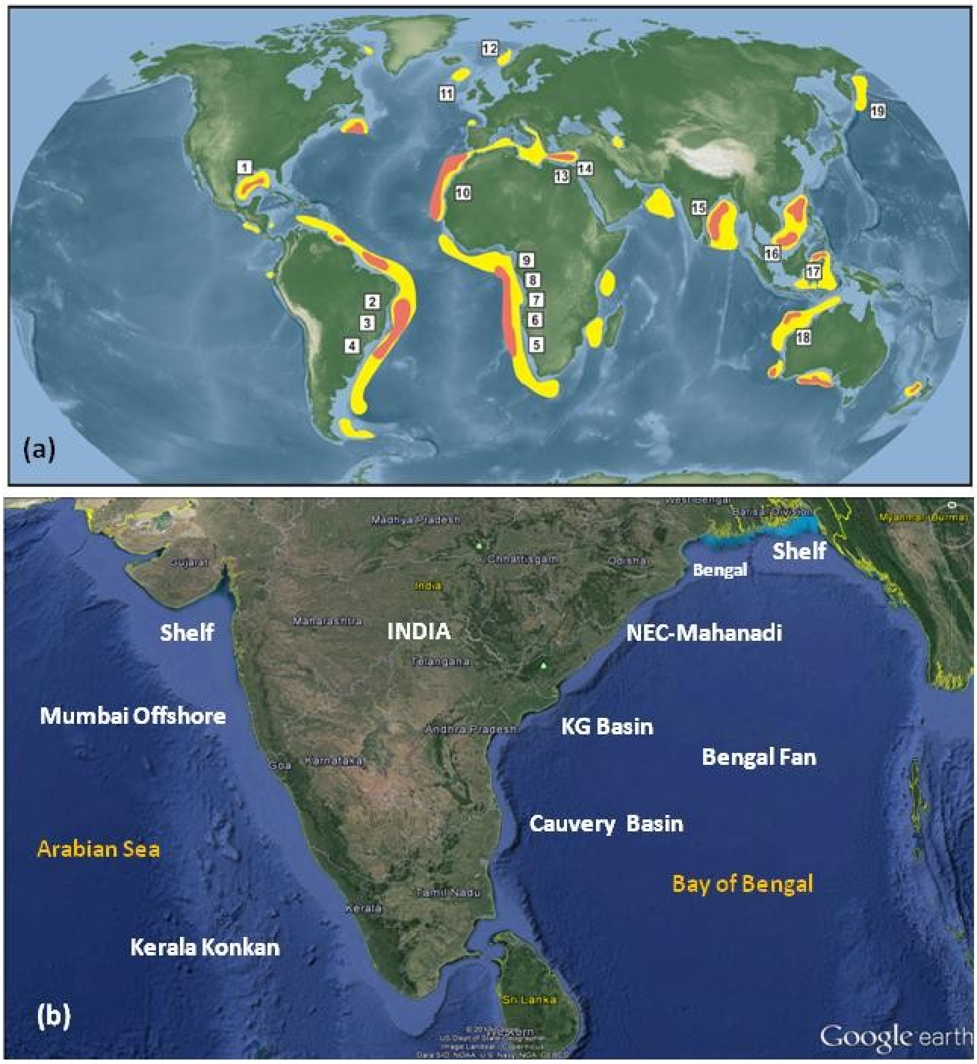

Figure 1: (a) Map showing the various deep water basins in the world (with production or announced discoveries): (1) northern Gulf of Mexico, (2) Sergipe-Alagoas (3) Campos (4) Santos, (5) Angola, (6) Gabon, (7) Congo, (8) Equatorial Guinea, (9) Niger Delta, (10) Mauritania, (11) offshore Shetlands Islands, UK, (12) mid-Norway, (13) Nile, (14) Israel, (15) Krishna-Godavari, (16) northwest Borneo (offshore Sabah), (17) eastern Borneo (offshore Mahakam delta), (18) northwest Australia, and (19) Sakhalin Island. Known source rocks for each basin are listed in Table 3. Yellow = deep-water basin. Red = ultra-deep-water basin. (Nilsen et al 2007, AAPG Atlas of Deep-Water outcrops)
(b) Map showing various deepwater basins of India. A number of discoveries have been reported from Krishna-Godavari (KG) deepwater region in the recent past.

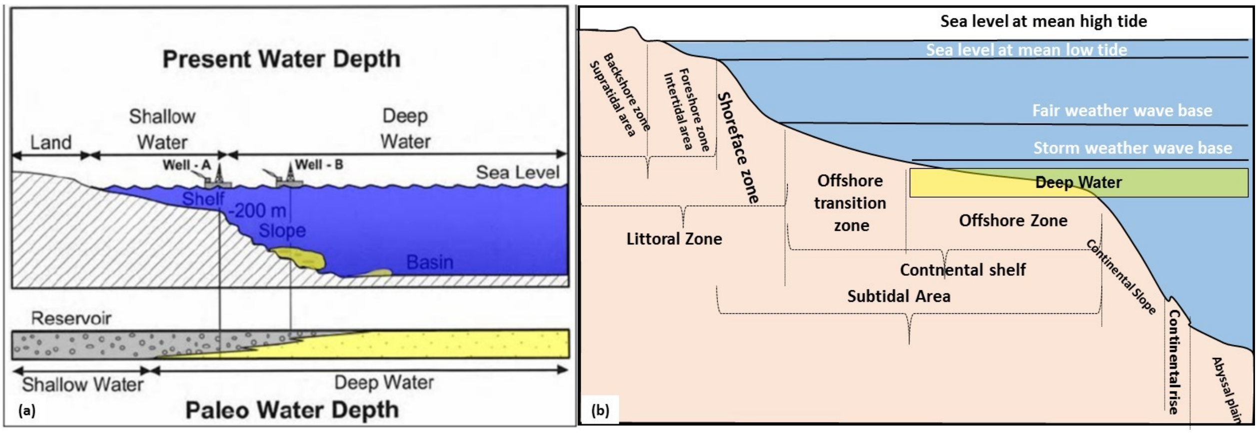

Figure 2: (a) *A schematic diagram defining "deepwater" (after Shanmugan 2000a). The term 'deepwater' denotes region that occur seaward of the continental shelf break on the slope and basin settings. In petroleum exploration and production, the term deep water is used with two different meanings. First, geologists use the term to denote sediments deposited in deep water, although the present day water depth in the region is shallow water (e.g., Well A). Drilling engineers use the term deepwater strictly for drilling depths (e.g., Well B), even if the target reservoir is of shallow-water origin. Grey color = reservoirs of shallow-water origin. Yellow color = reservoirs of deepwater origin. (modified After Shanmugam (2000a). (b) Another definition of Deepwater, which states that any deposition beyond storm weather wave base and towards the basin is called Deepwater. This is the region where sedimentation is more controlled by the gravity driven processes.*

Connecting Shelf to Deepwater

Understanding how sediment moves from shelf to deep water is quite crucial in characterizing deepwater system. Shelf region of a continental margin acts as a staging area for sediment dispersal into the deep water. Deposition of deep water systems is in part influenced by a variety of shelf margin and slope processes that affect the sediment pathways into the receiving basins. Topographic changes of seafloor of shelf and slope, which resulted from tectonic movement, and sea level changes can lead to switching in of the sediment pathways leading to deep water basins. Deep canyons found on the shelf and slopes are actually the conduit for sediment transportation. Figure 3 shows prominent shelf canyons found around the world. SONG or swatch of No ground in Bay of Bengal, is one of the prominent canyon which digs deep into the shelf sediment and also extends to the slope. Sediments transported by the Ganges-Brahmaputra delta system are redirected to the deepwater through this canyon. Figure 3b shows canyon on the Congo shelf, where the canyon can be seen to be almost merging with the inland river. Hence connecting shelf to deep water is one of the important steps in understanding deepwater sedimentation.

Sedimentation in Deep water environment

Sedimentation in deepwater environment is mostly done by gravity flows of sediments. Gravity flow deposits again can be classified as turbidite or debris flow based on rheological composition. Continental slopes or abyssal plains act as sink where vast sediment derived from shelf region is deposited.

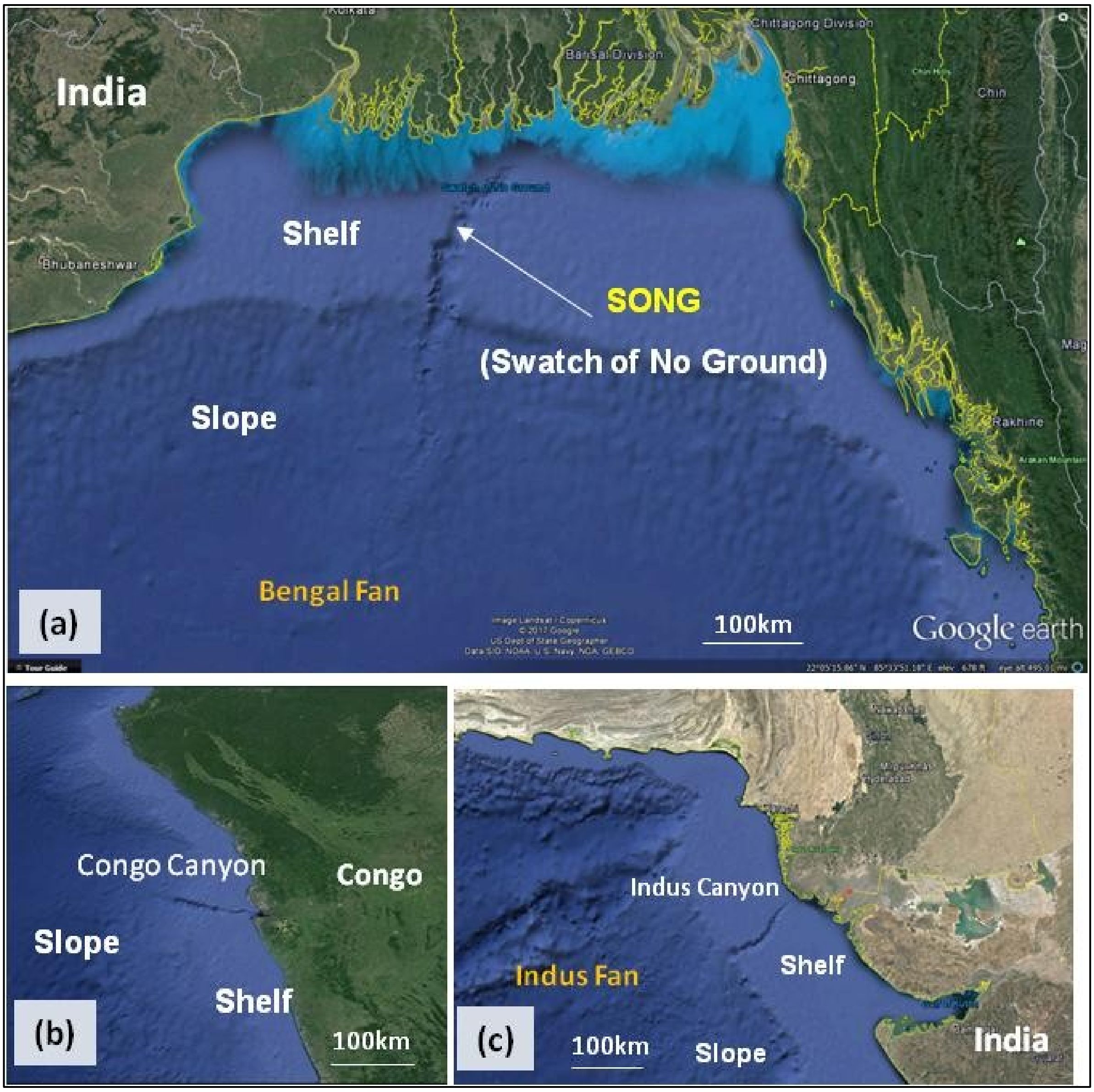

Figure 3: (a) Present day Topographic map showing Shelf canyon on the Bay of Bengal shelf, this is also termed as Swatch of No Ground or SONG. As can be seen from the map the canyon connects shelf to slope feeding to world's largest submarine fan. The depth of SONG is reported to be raning from few metres to more than one kilometre. (b) Topography map showing Congo canyon, which joins the Inland rivers to the deepwater slope. This canyon is one of the few examples in the world where the shelf canyon clearly connects the inland river systems to the slope region, hence enabling sediment from the river deltas going into the basin. (c) Shelf canyon for Indus fan, world's second largest submarine fan system.(image source: Google Earth)

A number of sedimentary processes active in deepwater region are presented in Figure 4. These processes, which are responsible for erosion, transportation and deposition of sediments, have been classified into the following groups, namely (Stow, 1992): (i) pelagic and hemi-pelagic settling associated with surface current, (ii) Semi-permanent bottom currents (contour currents) (iii) Re-sedimentation processes. Pelagic and hemi-pelagic deposits consist of very fine grain sediments which settle down from water. Re-sedimentation is the most important process as this process is responsible for emplacing terrigenous clastic deposits which can be good reservoir. As the name suggests, re-sedimentation process directs sediments from the shelf to deep water through various conduits and processes. There are also deepwater deposits which are reworked and deposited by bottom currents or contour currents.

Deepwater Depositional Elements:

As shown in figure 4a & b, a number of depositional features of varying shapes and sizes are identified in the deepwater system. While some of the features are resulted because of erosion, others are formed due to deposition of sediments. Brief descriptions of some of the major deep water depositional elements are discussed below:

Submarine Canyons: Submarine canyons are steep sided, straight to sinuous valleys (V or U-Shaped), with negative relief features, incised into the shelf or continental slope, that are formed by erosion of the substrate. These act as conduits for sediment transfer from shelf to deep water. Submarine Canyons consistently confine gravity flows of sediments whereas submarine channels only partially confine flows (Posamentier and Walker, 2006). A seismic attribute map demonstrating canyons on the shelf and associated deep water channels as well as fan complex is shown in Figure 5.This map clearly shows how the submarine channels originate from the canyon and also feed to the submarine fan.

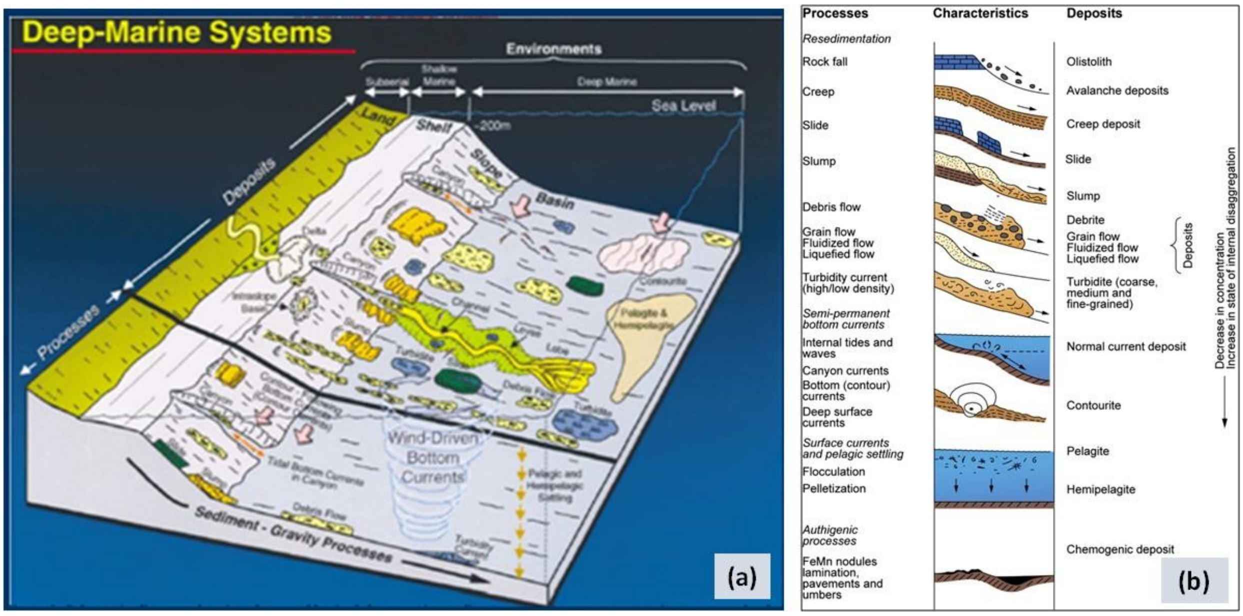

Figure 4: (a) Schematic diagram showing various depositional elements and processes in a deep water environment. While the shallow-marine (shelf) environments are characterized by tides and waves, deep-marine systems are characterized by mass flows (i.e. slides, slumps, grain flows, and debris flows), various bottom currents, and pelagic/hemi-pelagic deposition. Turbidity currents and debris flow are the most active and dominant processes in slope and basin setting. (After Shanmugam (2000a) (b) summary of various processes and resulting deposits found in deepwater environment, Processes and product of deepwater sedimentation (modified after Stow, 1994)

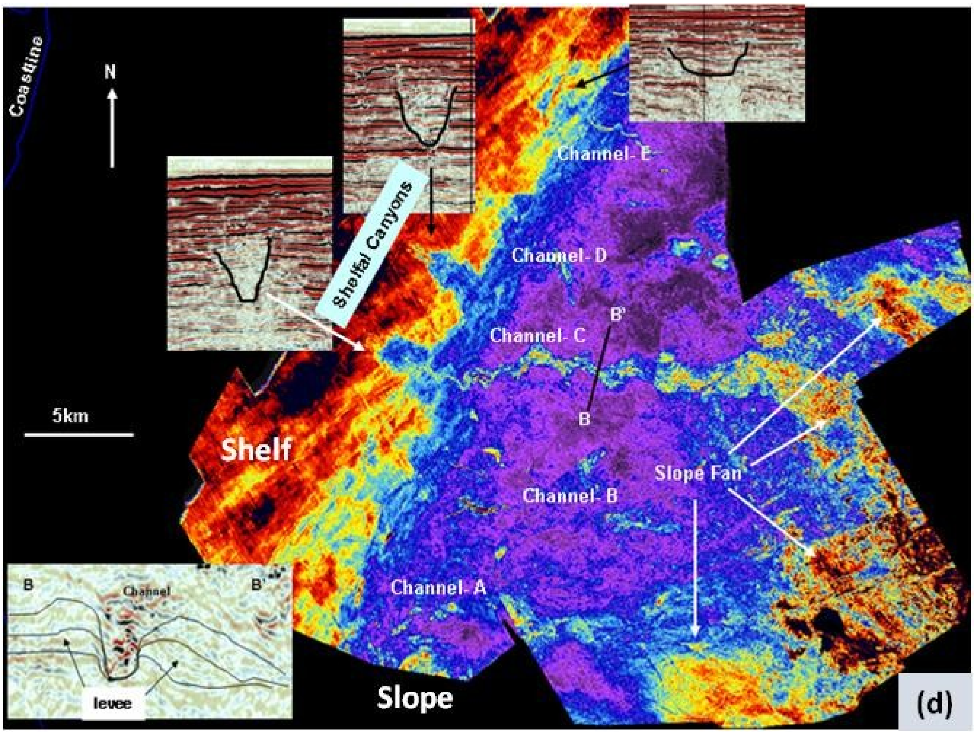

Figure 5: Amplitude map extracted along a surface showing well developed channels terminating in deep water slope fans. All the channels can be seen originating from slope canyons. Channel C is the most well developed one, showing sinuosity of 1.5. Channels A, C & E are found to be forming slope fans as we go to the basinal part. Drilled well results show these channels to be sand rich. The low amplitude seen around channels may be mud rich (Nayak et al 2008).

Salient Characteristics of Submarine canyons are:

- These area erosional features.
- Formed by erosion caused due to mass failure, debris flow, slides etc.
- The canyons act as a container for future deposition in form of channels, levees and lobes.
- Channel fills in the canyon can actually act as good reservoir

Submarine Channel

Submarine channels are morphological features that carry sediment from areas of higher topography to lower-lying regions via relatively narrow, elongate pathways with clear margins (Figure 6). Channels are characterized by presence of levee/ over bank deposits which are constructional in nature .Channels serve as conduits for gravity flows of sediments and show a variety of sediment infill and geometries. They can be found on the slope, at the base of the slope and on the basin floor. Well-developed channel system in Bengal basin was studied by Kolla et al, 2012, demonstrating external geometry as well as internal architecture of the channel and levees (Figure 7).

Salient Characteristics of Submarine Channels

- Channels are having similar geometry like fluvial channels
- Best locale for reservoir development and are major exploration targets.
- The channels could be highly sinuous or straight
- Channel fills could be associated with structural or stratigraphic traps.
- Could run up to hundreds of kilometres in length.

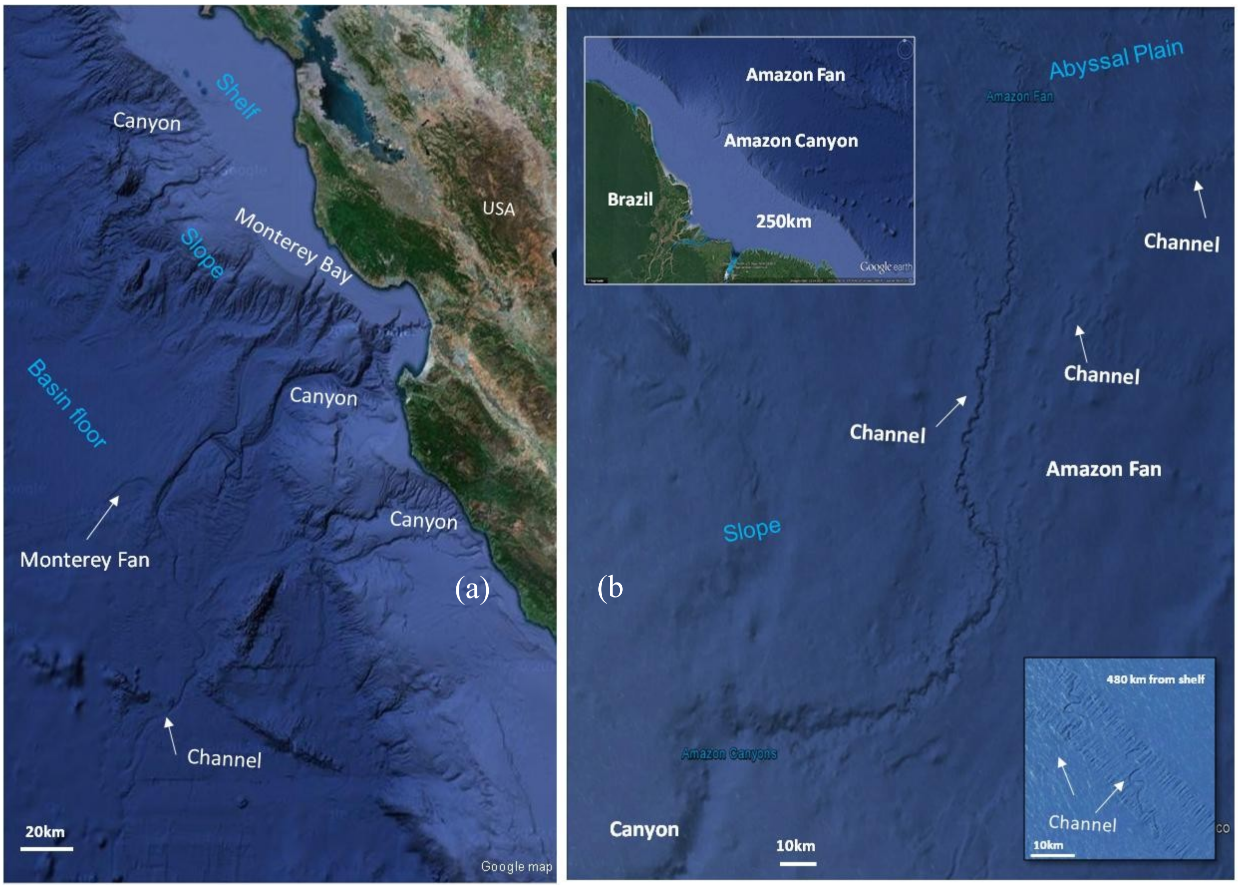

Figure 6: (a) Present day topography map showing present day shelf-slope architecture in the Monterey Bay area, western offshore USA. The water depth in the slope and basin region varies from few meters to more than 2000 m. These amazing images shows development of a number of canyons on the shelf slope break with the canyons seem to eroding head ward resulting in joining with the land river system. Sinuous channels which are of hundreds of kilometers long are found in the outer slope to basin region.(b) Present day bathymetry map showing prominent highly sinuous channel running from shelf slope break to more than 200 kilometres into the basin in Brazil offshore, with water depth ranging from few metres to more than 4000 m. The image in the inset shows zoomed view of sinuous channels which could be traced at more than 250 km from the shelf slope break with water depth more than 4 km. From the image it could be understood how far the submarine channel run even under immense column of water. (Image source: Google Earth)

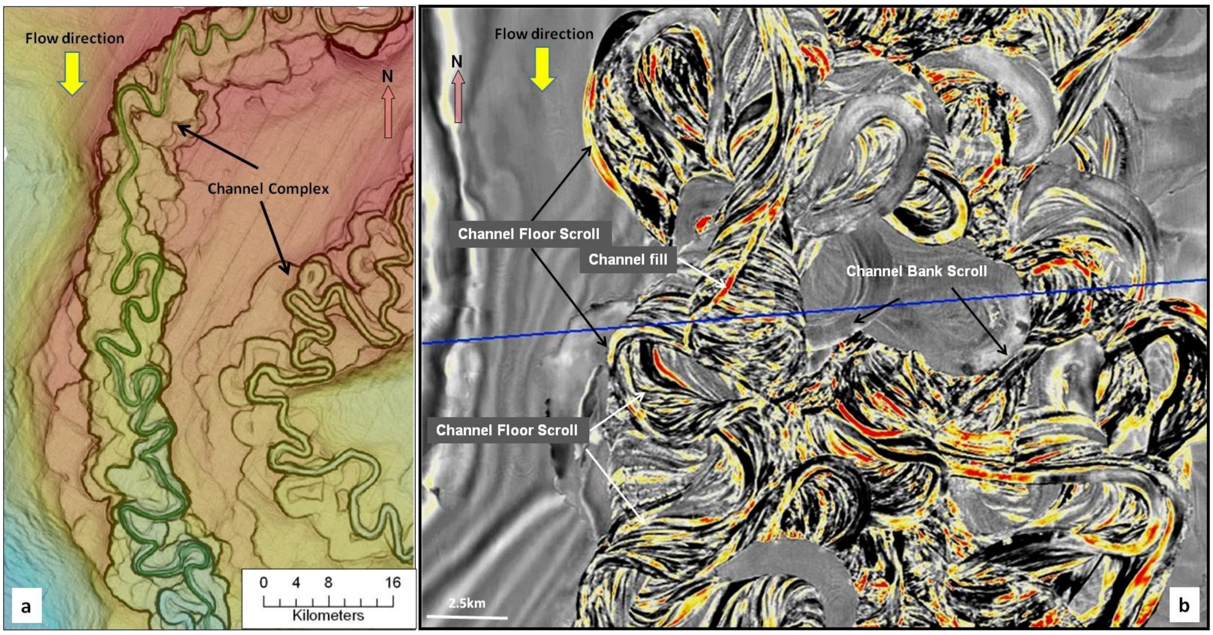

Figure 7: (a) Present day bathymetry interpretation from close grid 3D seismic data, Bay of Bengal. The channels are highly sinuous and run from north to south. The highly sinuous string like channel form at the center represents channel thalweg. Higher topography portion on the flank of the channel are known as terraces, formed by filling of older channel by younger levees and overbank. (b) A seismic time slice below sea bottom showing seismic impression of a highly complex channel system showing channel scroll bars resulted from lateral migration of channels with time. The hot colors (red or black) could suggest coarse grain or sand deposits within channel while the soft colors (grey) represents fine grain or shale fill deposits. (Kolla, 2012)

Submarine Levees/ overbank

These are positive relief features observed on the flanks of the channel. Levees comprise the deposits of low density turbidity currents which overspill on the outside of meander bends. They are intrinsically linked to depositional channels (see submarine channels) and are typically discussed in terms of channel-levee complexes. Levees capture the finer-grained sediments which escape from the channels during flow. For preliminary understanding the terms levees and overbanks could be used alternatively. The levees associated with the deep water channel could be divided into (i) Inner levee and (ii) Outer Levee. Inner levee is used for the portion between channel thalweg and the channel crest while Outer levee denotes the part between crest and termination of the levee against slope, fan or basin plain .Figure 8 shows seismic map expression as well as map views of the channel and levee system.

Salient Features of Levees/ Overbank

- Mostly comprises of fine grained material
- Still can act as good reservoir for hydrocarbon with broad lateral continuity.
- Levee height can go up to few hundred meters.
- Channels in fine grain system are having relatively large levee/ overbanks
- Levee thickness decreases away from the channel axis
- Levees can be classified into inner levees and outer levees.
- Levee height decreases as we move into the more basin direction

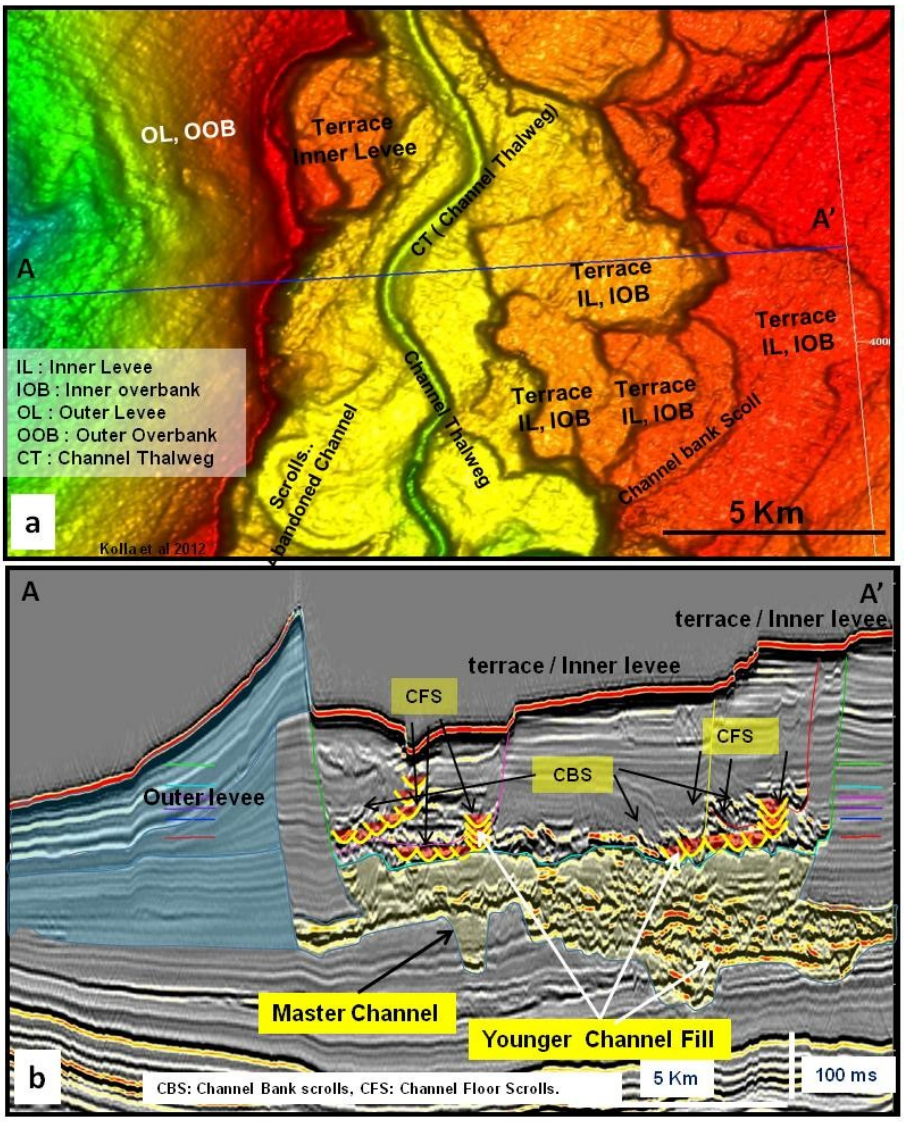

Figure 8: (a) Bathymetry map derived from close grid 3D seismic data in deepwater, Bay of Bengal. Channel thalweg, inner levees and outer levees could be easily identified from the map. (b) Arbitrary seismic section showing seismic impression of a deep water channel complex. The Chaotic seismic signature represents channel fills. As seen from the seismic section the chaotic seismic facies are distributed in various locations spatially and vertically representing lateral and vertical migration of the channel with time. A number of channel fills are interpreted to be constrained within a bigger master channel. On the flank of the channel low amplitude reflectors showing thickening near channel and thinning away from the channels are identified as levees or overbank deposits. Based on the seismic amplitude, the chaotic seismic reflectors with high amplitude are interpreted as sand bearing while the low amplitude reflectors are shale prone. (Kolla, 2012).

Submarine Fans

These are fan shaped bodies deposited on the slope or basin floor (Figure 9). They are generally considered to be constructional features on the basin floor and in intra-slope basins that develop seaward of a major sediment point source, such as a river or delta, or beyond a main cross slope supply route such as a canyon.

Salient Features of Submarine Fans

- These are constructional features, showing Bi-directional downlaps with thickest at Centre and thinning out at the ends.

- Submarine fans are found to contain very good quality clastic reservoirs.
- Fan may consist of numerous channels and associated elements.

Mass Transport Complexes (MTCs)

Mass transport complex denotes deposits resulted from various mass wasting processes like slide, slump, debris flow etc. MTCs are commonly identified on seismic data by contorted, chaotic and/ or low amplitude reflections (Figure 10). In many basins these forms the most dominant deep water deposits. MTCs could form by various processes like slope failure, tectonic activity, earthquake. These are not very good reservoirs and can act as good seals.

Salient Characteristics of Mass transport complexes (MTCs)

- MTCs are made up of sand and mud mixture, with dominant mud.
- Commonly identified on seismic data by contorted, chaotic and/ or low amplitude reflections contained within high amplitude base and top reflectors.
- These are not good reservoirs and act as good seals.

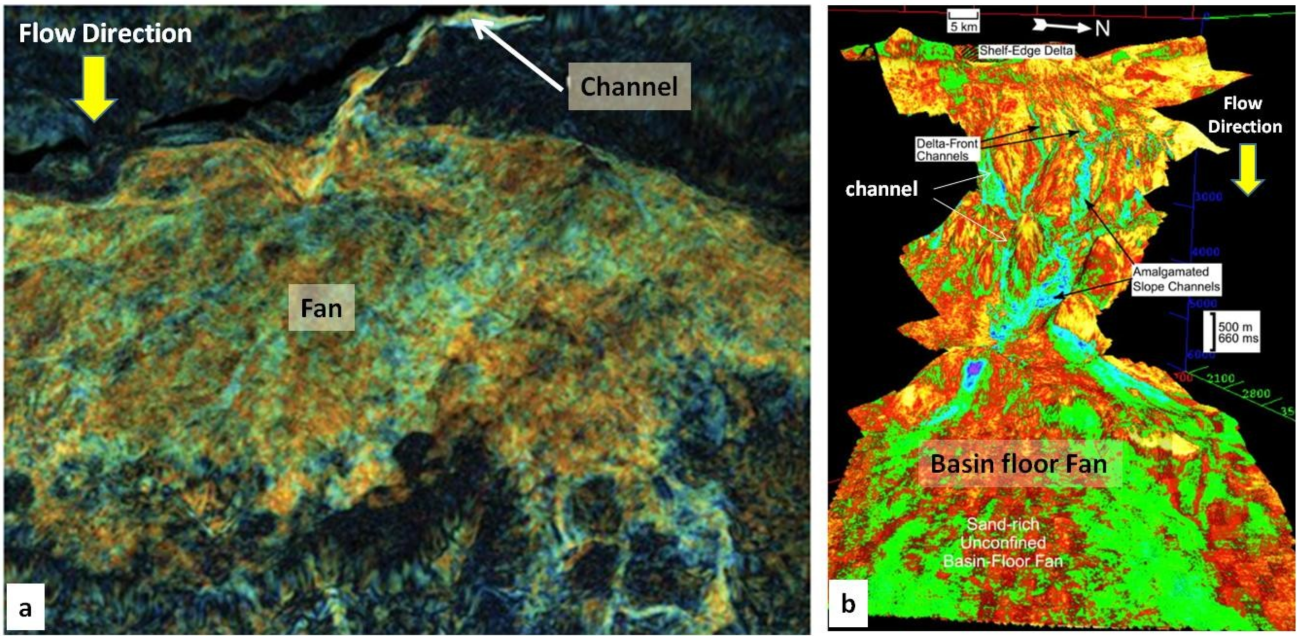

*Figure 9: (a) 3D perspective view of a spectral decomposition image of a Channel and associated deep water fan complex in Newfoundland. The sediments of the fan are seen to be sourced from the channel at the top (*Templeton K, 2017). *(b) Three-dimensional image from the north Kutai Basin (Indonesia) showing the connection of the Pleistocene basin-floor fan to a low stand delta formed during the 240,000-yr low stand of sea level. Blue is the highest amplitude and is generally inferred to be sand rich. Yellow color represents the lowest amplitudes, which are inferred to be shale rich. (Saller et al., 2004)*

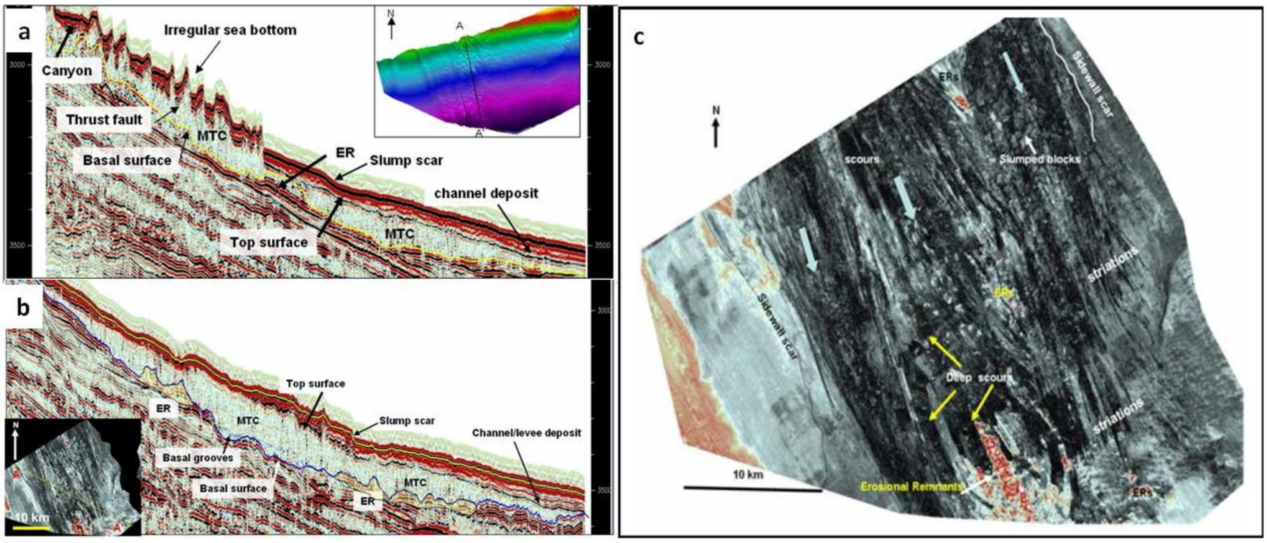

Figure 10: *(a) A seismic section along a near surface mass transport complex in offshore Krishna-Godavari basin, India. Base of the mass transport complex is highly erosional in nature. The irregular nature of the top surface of the MTC is because of the smaller scale thrust faults because of mass movement. As the thrust faults pierce through the sea bottom irregular topographic highs and lows are formed. Impression of these features could be seen on the water bottom map also (see inset). (b) An arbitrary seismic section across the MTC is showing development of grooves on the basal surface. These grooves represent erosion activities of the mtc. (c) Amplitude extracted along base of the MTC sowing various geomorphic features associated with basal surface. A number of striation marks can be seen running From NW to SE direction. Presence of a number of sets of striations marks suggests mass transport movement in different times. A number High amplitude bodies corresponding to the un-eroded blocks (erosional remnants) are seen to be present at the distal part.*

Sediment waves

Sediment waves are wavy seismic signatures looking like sand dunes of deserts and are mostly found on the deep water environment (Figure 11). Sediment waves may form in relation to overspill and flow stripping from the main channel (Posamentier et al., 2000; Posamentier and Kolla, 2003; Posamentier, 2003) and are found on flanks of the canyons, channels (on the levees, overbank). These sediment waves are morphologically similar to the straight-crested dune fields described for fluvial and shallow-water systems in the context of flow regime charts, excepting that they develop in much larger scales. From the orientation of sediment waves in relation to the main Channel, it may be inferred that they form preferentially in the extension of outer bends.

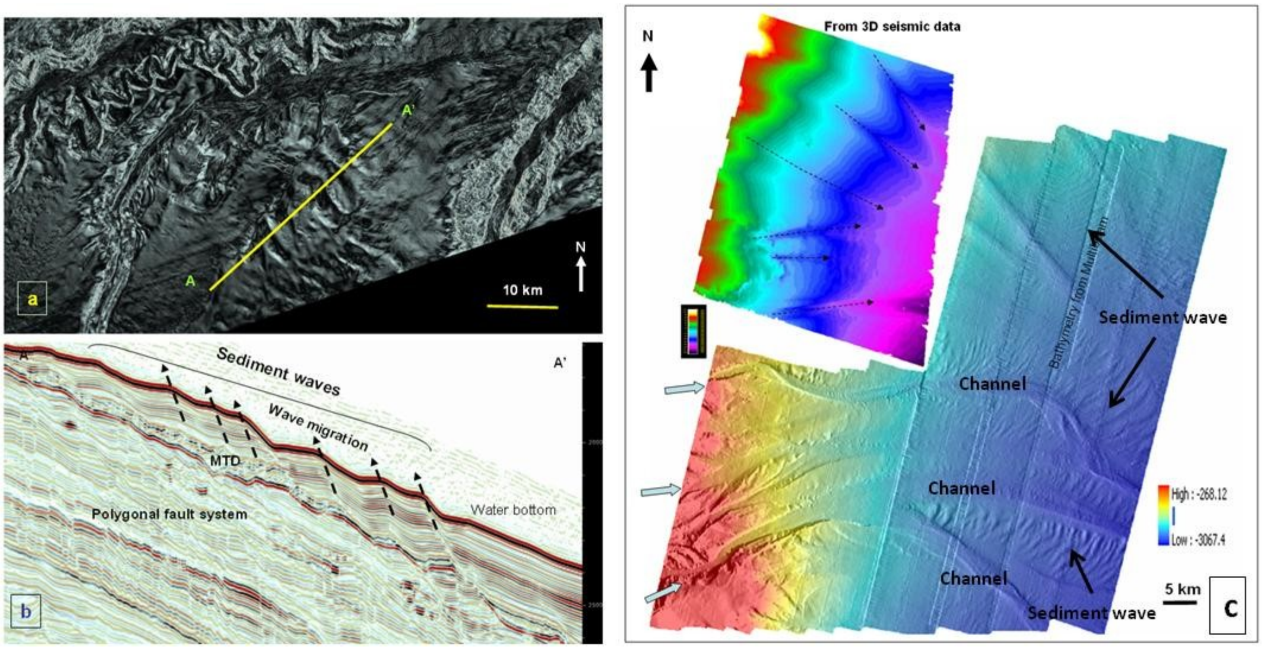

Figure 11: (a) Map showing dip Event Similarity Prediction (ESP) attribute extracted along water bottom. The wavy-ridge like features identified from the map represent sediment waves. Geomorphology wise these features could be correlated with the sand dunes found on the deserts, but process wise these are formed by various different processes in deepwater setting. b) An arbitrary seismic section showing seismic impression of sediment waves. The seismic reflection package below the sea bed shows wavy nature. These are identified as sediment waves. The crest of the ridges are found to be migrating upward.(c) Bathymetry map derived from seismic data and multi-beam data set showing prominent present day deepwater channels in offshore Cauvery basin (Bastia et al, 2011). Sediment waves are also clearly seen in between the channelized features.

Conclusion

In spite of recent focus on deep water exploration and production in worldwide basins, deep water environment still remains challenging due to the complex nature of depositional environment and processes. A number of deepwater basins around the world still remain unexplored with little idea on future prospectivity. With advent of high quality of 3D seismic data, seismic geomorphology could be a critical tool in deepwater exploration. Seismic attribute analyses are quite useful in characterizing deepwater depositional elements. Few examples shown in this paper represents the nature of image produced from 3D seismic data, which shows even small scale depositional elements. More focused study on the deep water system could be quite useful in understating the enigmatic deepwater system and assess future hydrocarbon potential of the basins.

REFERENCES

Bastia R., Radhakrishna M. and Nayak S. (2011) Identification and characterization of marine geo-hazards in the deep water eastern offshore of India; constraints from multi-beam bathymetry, side scan sonar and 3D high-resolution seismic data (*in* Tectonics of Bay of Bengal and Arabian Sea with special emphasis on coastal and marine geo-hazards) Natural Hazards, 57(1):107-120

Kolla, V., Bandyopadhyay A., Gupta, P., Mukherjee, B. and Ramana, D. V. (2012) Morphology and internal structure of a recent upper Bengal fan-valley complex, in B. E. Prather, M. E. Deptuck, D. Mohrig, B. Van Horn, and R.B. Wynn, eds., Application of the Principles of Seismic Geomorphology to Continental-Slope and Base-of-Slope Systems: Case Studies from Seafloor and Near-Seafloor Analogues: SEPM, Special Publication 99, p. 347–369.

Nayak S. (2009) Characterising deep water depositional elements and processes using near surface seismic data, eastern offshore basins, India. Unpublished Thesis, P.G. Department of Geology, Utkal University Orissa.

Nayak, S., Bastia R., Das M. (2008) Seismic stratigraphy and depositional architecture of quaternary-tertiary sediment in Krishna offshore, east coast of India. Jour. Indian Association of Sedimentologists, Vol. 27, No. 2, pp. 135-143

Nilsen, T. H., Shew, D. R., Steffens G. S. and Studlick R. J. (2007) The Atlas of Deep-Water Outcrops AAPG Studies in Geology, 56

Posamentier, H. (2003) Depositional elements associated with a basin floor channel–levee system: case study from the Gulf of Mexico. Marine and Petroleum Geology 20, 677–690.

Posamentier, H. W. and Kolla, V. (2003) Seismic geomorphology and stratigraphy of depositional elements in deep-water settings. Journal of Sedimentary Research 73, 367–388.

Posamentier, H. W. (2002) Ancient shelf ridges – A potentially significant component of the transgressive systems tract: Case study from offshore northwest Java. Amer. Assoc. Petrol. Geol.Bull., 86/1: 75-106

Saller, A., Werner, K., Sugiaman, F., Cebastiant, A., May, R., Glenn, D. and Barker, C. (2008) Characteristics of Pleistocene deep-water fan lobes and their application to an upper Miocene reservoir model, offshore East Kalimantan, Indonesia.DOI: 10.1306/03310807110

Shanmugam, G. (2000a) 50 years of the turbidite paradigm (1950s–1990s): deep-water processes and facies models—a critical perspective. Marine and Petroleum Geology 17, 285–342

Stow, D. A. V. (1994) "Deep-sea processes of sediment transport and deposition. In: Sediment Transport and Depositional Processes", ed. by K. Pye, Blackwell Sci. Publ. pp 257-293

Templeton, K. (2017) Newfoundland and Labrador groups striving to unlock region's offshore potential. http://www.offshore-mag.com/articles/print/volume-77/issue-2/offshore-canada/newfoundland-and-labrador-groups-striving-to-unlock-region-s-offshore-potential.html

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AN OVERVIEW OF TALC MINERALISATION IN RAKHABDEV ULTRAMAFIC SUITE & ITS PETROGRAPHIC INVESTIGATIONS

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ABSTRACT

During the synorogenic phases of the Aravalli Geological Cycle, the Rakhabdev Ultramafic Suite intruded concordantly along the litho-contacts before beginning and during the first phase of Aravalli folding. The ultramafic rocks consist mainly of serpentinites and are extensively altered and metamorphosed to talc-carbonate rocks and talc and chlorite schists. The talc and talc schist (Steatite) bodies are present in the form of lenticular and irregular pockets, veins showing pinch and swell nature and impersistent bands in serpentinites. The ultramafic bodies show lithological zoning, with a massive core and irregularly broken Serpentinite surrounded successively by the zone of less-foliated and sheared talc-serpentine (Carbonate-Tremolite-Actinolite) rock; foliated and sheared Talc-Carbonate (Tremolite) rock; Talc-schist and Tremolite-Actinolite-Talc-bearing Dolomite and Tremolite-Actinolite (Chlorite-Talc) schist.

Steatisation is much later to Serpentinisation. The process of steatisation can be attributed to carbon-dioxide metasomatism, shearing and metamorphic activities. At some places talc, tremolite, actinolite and chlorite, associated with dolomitic patches, are the products of regional metamorphism of these rocks under green schist facies condition. Evidences are also available which indicates that the dolomitisation of serpentinites is due to replacement process. With increasing metamorphism, steatisation of dolomite take place particularly along shear planes, which seems to facilitate development of talc. In Rakhabdev Ultramafic Suite three stages of development of talc schist lenses are observed. These are (1) Fine disseminations of talc within dolomite, (2) Progressive steatisation with increasing metamorphism, (3) Complete steatisation of dolomite.

Keywords: *Ultramafic rocks, Serpentinites, Steatisation, Metamorphism, Aravalli Supergroup*

INTRODUCTION

During the Aravalli Geological Cycle, there were three main events of magmatism. An extensive shoreline syn-sedimentational basic volcanism, named as the Delwara-Siri Volcanics, occurs almost all along the base of the Aravalli Supergroup. Rakhabdev Ultramafic Suite of rocks intruded concordantly during the synorogenic phases of the Aravalli Geological Cycle. These ultramafic rocks found in southern part of Rajasthan consist predominantly of serpentinite and are extensively altered and metamorphosed to talc-carbonate rocks along with talc and chlorite schists. Further rise of geo-isotherms led to widespread migmatisation and emplacement of syn-orogenic to late-orogenic granites (viz. in Udaipur, Udaisagar, Salumber, Darwal and Titri areas).

RAKHABDEV ULTRAMAFIC SUITE

Rakhabdev Ultramafic Suite occurring in Antaliya-Rakhabdev-Kherwara-Dehlana area has been considered to have intruded concordantly along the litho-contacts before and during the first phase of Aravalli folding and is subsequently folded along with metasediments. These ultramafic rocks consist predominantly of serpentinite and are extensively altered and metamorphosed to talc-carbonate rocks, talc and chlorite schist. These rocks occur as large, irregular lensoid bodies of more than 5 km length within the Aravalli Supergroup of rocks in three different belts. The first belt extends from Dad in Dungarpur district in the SE to Sero-ki-pal in the north over a distance of 77 km, the second from Kanthria to Kaliguman over a distance of 115 km and the third from Kaunthal to Titri over a distance of 15 km. In Antaliya area, the ultramafic bodies are very small, lensoid or oval-shaped. The Rakhabdev Ultramafic Suit occurs along two prominent lineaments (the Rakhabdev and the Kaliguman Lineaments) indicative of a deep-seated mantle tapping fracture.

SERPENTINITES AND SERPENTINITE-TALC ROCKS

The ultramafics consisting of serpentinites and serpentinite-talc rocks occur from Dad in south to Sero-ki-pal in the north and from Kanthria to Kaliguman, and between Kaunthal and Titri intermittently for over 200 km. The main occurrence between Dad and Sero-ki-pal through Rakabdev, is the widest (About 5 km) at Rakabdev. These ultrabasic rocks were considered to be Post-Delhi intrusives (Heron, 1953), but the recent study of their structural setting has indicated that these were emplaced during early stage of Aravalli orogeny (Mathur, 1966; Rakshit, 1969; Chattopadhyay, 1975; Basu and Arora, 1968; Arora, 1971).

Serpentines have been formed due to complete serpentinisation of ultramafic rocks; as a result of which no trace of the original texture or composition is traceable. These rocks show shades of green color, varying in deep-green, pistachio green, apple green, greenish yellow and in varying greenish shades. These rocks are predominantly compact, tough, translucent to sub transparent, dense, fine to medium grained breaking with a splintery to conchoidal fracture and have smooth, greasy and wax like appearance.

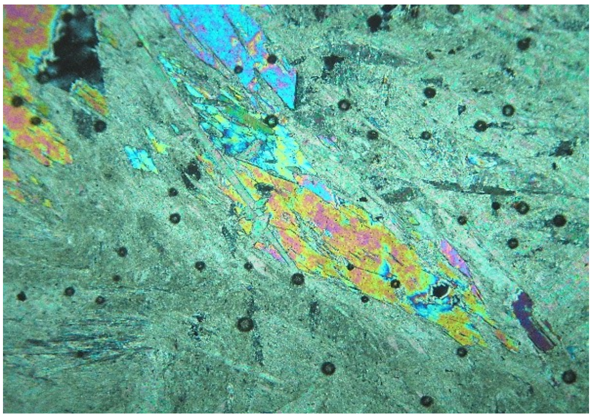
At places, extensive deformation and shearing render the rock highly jointed, fractured and crudely-foliated. In the foliated varieties development of carbonates, chlorite and talc is seen. The soapstone and talc represent alteration products of serpentinites and dolomites associated with the Aravalli metasediments, which have been subjected to polyphase folding, faulting and granitic intrusion.

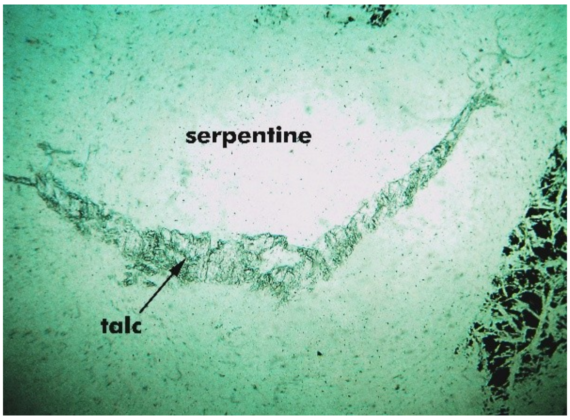
The Talc and Steatite bodies occur in a variety of forms viz. lenticular and irregular pockets, pinch and swell veins and impersistent bands in Serpentinites. The ultramafic bodies show lithological zoning, with a massive core and irregularly broken Serpentinite surrounded successively by the zone of less-foliated and sheared talc-serpentine (Carbonate-Tremolite-Actinolite) rock; foliated and sheared Talc-Cabonate (Tremolite) rock; Talc-schist and Tremolite-Actinolite-Talc-bearing Dolomite and Tremolite-Actinolite (Chlorite-Talc) schist (Fig. 1-A). This zone is impersistent and at places absent.

Talc and Soapstone occur along the sheared contact of Talc-Carbonate rock or within the Talc-Serpentinite rock. Talc veins also occur within the core of massive Serpentinites (Fig. 1-B). Flaky or fibrous Talc is associated with the ultramafics and form disseminations, aggregates, local concentrations and veinlets. The workable deposit occurs as large lenses, vein and bands.

The Talc bodies generally follow N 300° - 320° to N 120° - 140° trend parallel to the foliation of country rocks and general trend of ultramafic bodies. Foliated, flaky and fibrous greenish Talc, showing cross-fibres also occur as veins in shears and fractures trending N20°-40° to N 200° - 220°. The calcareous horizons appear to be favorable locales for emplacement of Serpentinite bodies. Steatisation is much later to Serpentinisation. The Steatisation is a result of metasomatic processes associated with hydrothermal, metamorphic and shearing activities.

Talc occurs as alteration product of serpentine minerals (particularly Antigorite and Chrysotile), Tremolite and Dolomite by addition of CO_2, H_2O or ionic replacement. The magnesia removed from these minerals has crystallized as Magnesite ($MgCO_3$) at places. Aggregates and vein of Calcite also occur in the Soapstone.





1-A 1-B

Figure-1: 1-A: Talc with Tremolite in a Schist. 1-B: Talc in a Serpentinites.

Talc-Carbonate rock and Talc-Carbonate Schist are grayish brown to grayish-white in color and comprise an admixture of talc, chlorite dolomite, and other carbonate and calc-silicate minerals. Amidst the talc-carbonate rock, bands, lenses, patches and knots of brownish, unaltered dolomite are frequently seen, which indicate their derivation from dolomite due to its alteration, along margins by steatisation due to hydrothermal solutions. At the culmination of steatisation a grayish-green to green-colored talc is developed at many places.

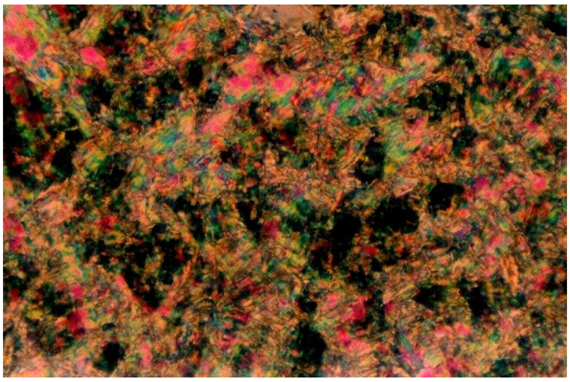
The process of steatisation can be attributed to carbon-dioxide metasomatism, shearing and metamorphic activities. Some of talc, tremolite, actinolite and chlorite associated with dolomitic patches are the products of regional metamorphism of these rocks under green schist facies condition (Rakshit, 1968). Field evidences indicate that dolomitisation of serpentinites is due to replacement process. With increasing metamorphism, steatisation of dolomite took place, particularly along shear planes, which seems to facilitate development of talc.

Abundant lenses of talc schist (steatite) are developed within the talc carbonate rocks. Development of talc seems to have been particularly facilitated by shearing within these rocks. The three stages of development of talc schist lenses (Chattopadhyay, 1975) observed are fine disseminations of talc mainly within dolomite, progressive steatisation with increasing metamorphism resulting in very coarse-flakes of talc with isolated large grains of dolomite and finally, complete steatisation of dolomite.

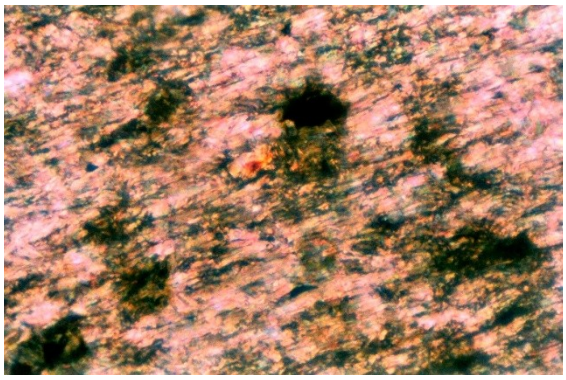
PETROGRAPHIC INVESTIGATION

In thin sections the rocks show a parallel orientation of talc. In these thin sections talc is present in different shades of colors varying from light green to light brown (Fig. 2-A and 2-B). Occasionally it is colorless. The talc occurs in fibrous aggregates and in the form of Shreds, which are aligned parallel; while shred and plates are often bent (Fig. 2-C).

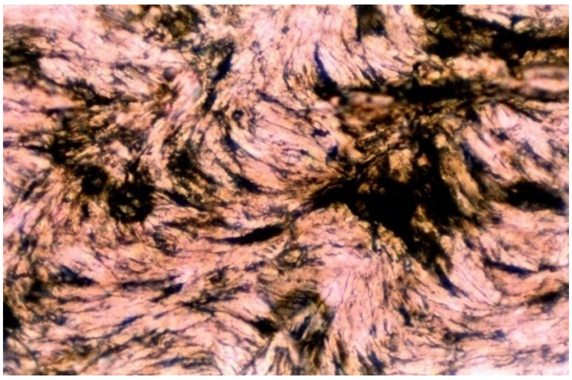
Talc shows perfect cleavage in one direction (001), but talc in some sections lacks cleavage due to the effect of metamorphism. Number of tiny dolomite grains are scattered throughout and appears as if these have been transformed into talc (Fig. 2-D).



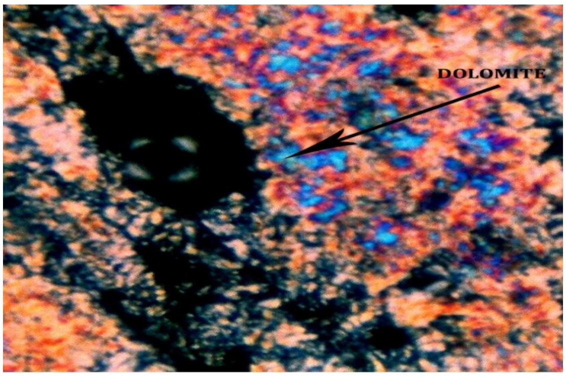
2-A



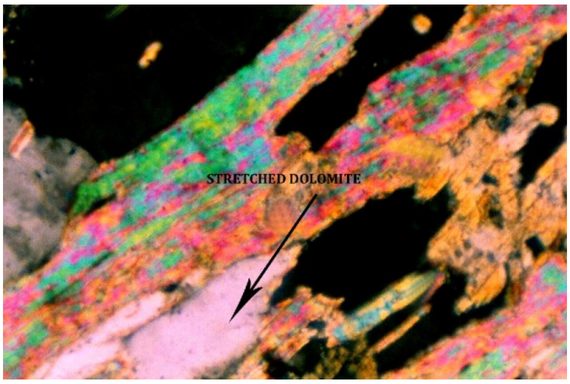
2-B



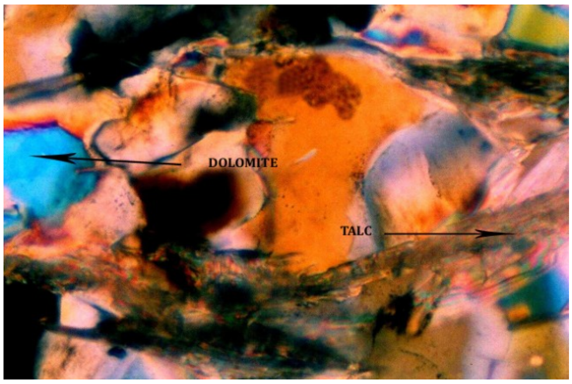
2-C



2-D

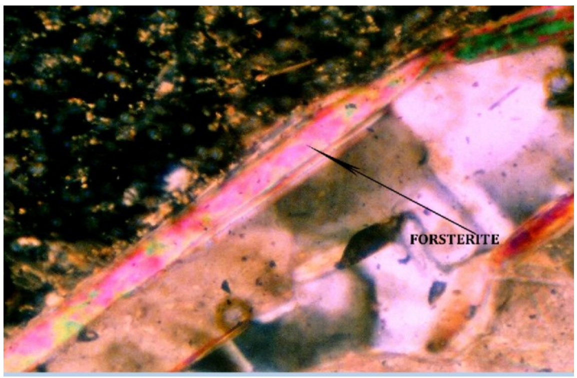


2-E



2-F

2-G



2-H

Figure-2: 2-A & 2-B: Different shades of Talc, 2-C: Fibrous aggregates of Talc in the form of Shreds, 2-D: Blue colour shows grains of Dolomite, 2-E: Stretched Dolomite grains aligned parallely, 2-F: Rhombohedral form of Dolomite due to metamorphism, 2-G: Tremolite aligned parallel to schistocity plane, 2-H: Forsterite indicating the threshold of low amphibolite facies

The dolomite grains are found parallel to schistocity. The dolomite grains are stretched and aligned parallel to each other and show glide twinning (Fig. 2-E). As an effect of metamorphism, original rhombohedron form of Dolomite is rarely noticed (Fig. 2-F). Generally dolomites show white, often tinged with yellow or brown color. The extinction angle varies from 20° to 40° which make it distinct from calcite.

The assemblage Chlorite-Talc-Tremolite observed in thin sections indicates the rock to be of green schist facies. The tremolite grains are needle shaped showing gray color but a few give light green color and may be Actinolite. The talcs show brownish color and are massive foliated, sometimes fibrous aggregates and exhibiting {001} cleavage. Chlorite shows weak pleochroism from light green to light brown color. Pleochroism in chlorite increases with higher iron content. Pleochroic haloes are also noted, and may be zircon at the centre of haloes. The margins of talc are frequently transformed into tremolite. The tremolite is aligned almost parallel to the schistocity plane (Fig: 2-G). In very few tremolites the tint of Diopside/ Forsterite are noticed indicating at the threshold of low amphibolite facies (Fig: 2-H).

REFERENCES

Arora,Y. K. and Ramachandran, K. R. (1971) Report on Systematic Geological Mapping in the Richer-Kelwara area, Udaipur districts, Rajasthan. (Unpublished Report) Geol. Surv. Ind. (F.S.1970-71).

Basu, K. K., Mukherjee, K. K., Das Gupta, S. and Arora, Y. K. (1968) Systamatic Geological Mapping in part of Udaipur districts, (Toposheets Nos. 45 G/16 and 45 H/13), Rajasthan. (Unpublished Report) Geol. Surv. Ind. (F.S.1966-67).

Chattopadhyay, N. (1975) Investigation of Ultramafic Rocks in part of Udaipur and Dungerpur districts, Rajasthan. (Unpublished Report) Geol. Surv. Ind. (F.S. 1968-69).

Heron, A. M. (1953) Geology of Central Rajputana. Mem. Geological Survey of India, Vol. 79, pp. 1-389.

Mathur, R. K. (1966) Prelimnary Report on Investigation of Ultrabasic rocks in Udaipur, Rajasthan-Nickel, Chromium, Platinum and Asbestose minerals, (Unpublished Report) Geol. Surv. Ind. (F.S. 1968-69).

Rakshit, A. M. (1969) Report on Geology of Samder-Jawas and Kolicupur areas in part of Udaipur and Dungarpur districts, Rajasthan. (Unpublished Report) Geol. Surv. Ind.(F.S. 1968-69).

Gupta, S. N., Arora, Y. K., Mathur, R. K., Iqballuddin, Prasad, B. Sahai,T. N., and Sharma, S. B. (1997) The Precambrian Geology of the Aravalli region, Southern Rajasthan and Northeastern Gujarat. Memoirs Geological Survey of India, Volume-123, pp 190

Srivastave, N. (2007) Exploration of Soapstone Deposit around Devpura, Distt. Udaipur, Rajasthan. Unpublished Ph.D. Thesis, Bikaner University, Bikaner. pp 106-207.

www.und.nodak.edu/instruct/mineral/320petrology/opticalmineralogy

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SGAT News

- **53rd meeting of State Geological Programming Board** was organised in Hotel Mayfair Lagoon, Bhubaneswar on 19th July 2017. Mr R K Sharma, Principal Secretary to Govt. of Odisha, Steel & Mines Department chaired in the meeting. SGAT was represented by Dr B M Faruque and Mr J R Patnaik. Society suggested for prioritization of sectors like Bhalukasuni-Nilgiri chromite prospect in Balasore and Ramagiri chromite, Koraput; Geophysical survey and exploration in Kenduguda, Karabira, Seramunda, Kutragarh; examination of shear zones in Gumlai-Phasimal between Singhbhum craton and EGMB with NGCM data and study of Rare Earth Elements in Nepheline Syenite and Carbonatites of Odisha.

- **Prof Dr (Ms) Madhumita Das was felicitated** on 31st July 2017 by the Executive Council of SGAT at SGAT building, Bhubaneswar on her appointment as the new Vice-Chancellor of Fakir Mohan University, Balasore, Odisha.

- **Mineral Development Awareness and Quiz Programme (MDAQP)** was organised by SGAT during 18-20 August 2017 at Joda. The programme was collaborated by the Department of Steel & Mines, Govt. of Odisha and was sponsored by Tata Steel with Rungta Mines Ltd, Tata Sponge Iron Ltd and Essel Mining Industries Limited extending admirable support. The institutions who participated in the programme included Indian School of Mines, Dhanbad; IITs, Kharagpur and Bhubaneswar; IIEST, Shibpur; NITs, Rourkela, Jamhedpur and Raipur; Government College of Engineering, Keonjhargarh; Utkal, Sambalpur and Ravenshaw Universities; DD Autonomous College, Keonjhar; University College of Engineering, Kothagudem (Telengana); AKS University, Satna (MP); IGIT, Sarang among others. The activities under this programme included identification of rocks, ores, minerals, metallurgical products and photographs; interpretation of satellite imageries; visits to Joda West Manganese mine, Jajang Iron Ore mine, Joda East Iron ore mine; Ferromanganese and Sponge Iron Plants; Plantation; Environment protection measures; Water harvesting structure; haulage; loading and unloading systems among others. Oral quiz was the last activity. Department of Mining Engineering of IIEST, Shibpur emerged as the overall best team in the event. Society was represented by Mr B K Mohanty, Mr T Mohanta, Mr A B Panigrahi and Mr S K Mohanty. The event was coordinated by Mr B K Mohanty, Advisor, SGAT.

- **Remake of the Documentary film on "Mining and Environment"** has been accomplished keeping in view the changes that have taken place in the various mining and industrial regions of Odisha. Shooting of various aspects included mines, plants, processing, beneficiation, haulage, loading, plantation, exemplary environment protection measures, different locations of vulnerable rivers etc. Film has been produced in both English and Odia languages. Odia version has been telecasted in Kalinga TV channel. This film is being shown in different occasions of SGAT in order to bring awareness among the mass on the mining environment.

- Ministry of Mines, Govt. of India and Steel & Mines Department of Govt. of Odisha have brought out several draft legislations seeking comments of various stakeholders. Accordingly, **Society has**

studied and offered comments on draft National Steel Policy, 2017; National Mineral Policy, 2017; Mineral (Auction) (Amendment) Rules, 2017; Odisha Minor Mineral Concession Rules, 2016 and Gemstone Policy of Odisha 2017.

- In accordance with the resolution of the 36th AGB meeting, the amended **Memorandum and Articles of Association** (as amended up to 4 December 2016) of the Society has been finalized.

- Society has applied to Secretary, Mines, Govt. of India and CGPB, Delhi with a **request to nominate SGAT as a Permanent/ Special Invitee to CGPB (Central) and CGPB Sub-committees I, III, V and VI.**

- **The Workshop on "Mineral sector of India – post MMDR Amendment Act, 2015"** was held on 17 December 2017 at SGAT Building. A total of ninety two delegates representing various organisations including Geological Survey of India, Oil and Natural Gas Corporation, Department of Steel and Mines, Govt. of Odisha; Odisha Mining Corporation, Tata Steel, Tata Sponge Iron, Hindalco Industries, Jindal Steel & Power, Essel Mining and Industries, Rungta Mines, Vedanta, OCL India, MGM Minerals, SNM Group participated in the Workshop. Inaugural function was graced by the Chief Guest Sri Deepak Mohanty, Director of Mines, Govt. of Odisha who delivered the key note address. Dr S K Tamotia, former CMD, NALCO was the Guest of Honour. Eleven technical papers were presented in two technical sessions. Authors represented MoEF & CC, Geological Survey of India, Department of Steel & Mines - Govt. of Odisha, Tata Steel, Tata Sponge, OCL India, Jindal Steel and Power Limited, Essel Mining & Industries and Geological Society of India. Besides, Sri A B Panigrahi, former Controller of Mines, IBM and Sri R N Sahu, Mining Law Consultant presented papers. The Technical Session 1 was chaired by Sri Deepak Mohanty, Director of Mines, Govt. of Odisha and Sri Sanjay Patnaik, Managing Director, Tata Sponge and President, FIMI. The Technical Session 2 was chaired by Sri Ashok Parija, President, Odisha High Court Bar Association and Sri Sudhakar Adhikaree, Senior Resource Consultant. Valedictory session recorded the observations of the delegates and recommendations submitted by the Panelists. At the end Sri A B Panigrahi, former Controller of Mines, IBM offered formal vote of thanks.

- **37th Annual General Body meeting** was held on 17 December 2017. Seventy three members attended the meeting. Prof. Dr Omkar Nath Mohanty, Vice President presided over the meeting. One minute silence was observed by all as a mark of respect to the departed souls of SGAT Life members, namely, Ramdas Agrawal, S N Padhi, Biswanath Dash, Ajit Kumar Patnaik, P S R Reddy, K N Adhikari and R P Das. Prof. Mohanty delivered the welcome address. Proceeding of 36th AGB meeting held on 4 December 2016 was confirmed. Sri S K Mohanty, General Secretary presented the Annual Report for the year 2016-17. Report on Audited Annual Accounts for the Financial Year 2016-17 (Assessment Year 2017-18) was submitted by T Mohanta, Treasurer and the report was accepted by the General Body. Mr Bhabani Shankar Padhi, Chartered Accountant, was appointed as the Auditor for the Financial Year 2017-18 (Assessment Year 2018-19). It was proposed to enhance the Life membership fees of SGAT to Rs 3500 from the existing Rs 2500 and to Rs 2500 from the existing Rs 1500 for new members who are below 60 years age and are 60 years age and above respectively. The proposal was accepted after discussion. Programmes for the year 2017-18, as proposed, were approved by the House. K S Mohapatra Memorial Lecture was delivered by Prof. M C Dash, former Chairman, OSPCB and former Vice-Chancellor, Sambalpur University. SGAT Awards 2018 were conferred on the following personalities as detailed below.

- SGAT Lifetime Achievement Award 2017: Dr V P Upadhyay
- SGAT Award of Excellence 2017: Sri Subhajyoti Das
- Sitaram Rungta Memorial Award 2017: Dr Lopamudra Panda
- H H Read Memorial Gold Medal Award 2017: Sri Jayant Kumar Nanda
- B C Patnaik Memorial Award 2017: Dr Satyabrata Nayak
- Best Paper Award 2017: Dr Debananda Beura

Prof. O N Mohanty, Vice President announced the election results for Executive Council 2017-19 term. 30 members including President, two Vice Presidents, General Secretary, two Joint Secretaries, Treasurer and 23 Council members got elected to the Executive Council. At the end, vote of thanks was offered by Dr S C Mahala.

11th International Earth Science Olympiad

Punya Pratyusha Sethi of D.A.V. Public School, Unit-8, Bhubaneswar, who appeared in the Entrance Test of International Earth Science Olympiad held on 22nd January 2017 at SGAT Centre, Bhubaneswar, scored highest mark in the Centre and ranked 8th in all India basis. She later succeeded in the Indian National Earth Science Olympiad and was selected as one among the four students who formed Team India and participated in the 11th IESO held from 22nd to 30th August, 2017 at the Sophia Antipolis Science & Technology Park, Cote d’ Azur, Nice, France. Other members of Team India included Advait Ganapathy (The Doon School, Dehradun), Raghav Sharma (Nalanda Academy, Kota) and Hiya Kwatra (Bharatiya Vidya Bhavan, Chandigarh). Punya Pratyusha Sethi won a Bronze Medal in individual category and a Gold Medal in the International Team Field Investigation (ITFI) activity.

Prof Dr Madhumita Das being felicitated on 31.07.2017 for being appointed as Vice-Chancellor, Fakir Mohan University

71st Independence Day being celebrated at SGAT building, Bhubaneswar

Participants of MDAQP 2017 being explained the rock and mineral samples on 18.08.2017 at Joda Valley Club

Participants of MDAQP 2017 being explained the the interpretation of satellite images on 18.08.2017 at Joda Valley Club

Identification of ores and industrial products during MDAQP 2017 at Joda Valley Club on 18.08.2017

Participants of MDAQP 2017 visiting Tata Sponge Iron Plant, Bileipada on 19.08.2017

Participants of MDAQP 2017 visiting Joda West Manganese Mines of Tata Steel on 19.08.2017

Oral Quiz Programme of MDAQP on 20.08.2017 at Valley Club Joda

Guests being welcomed on dais during the Valedictory Session of MDAQP on 20.08.2017 at Valley Club Joda

Guests on dais during the Valedictory Session of MDAQP on 20.08.2017 at Valley Club Joda

Valedictory Session of MDAQP on 20.08.2017 at Valley Club Joda

Mr Sanjay Pattnaik, MD, TSIL addressing the participants in the Valedictory Session of MDAQP on 20.08.2017 at Valley Club Joda

Mr Pankaj Satija, GM (OMQ), Tata Steel awarding the Winner Trophy to Mining Engineering students of IIEST, Shibpur

Inaugural Session of the workshop on "Mineral Sector of India – post MMDR Amendment Act, 2015" on 17.12.2017 at SGAT building, Bhubaneswar

Guests on dais during the inaugural session of the workshop on "Mineral Sector of India – post MMDR Amendment Act, 2015" on 17.12.2017

Mr Deepak Mohanty, Director of Mines, Odisha delivering key note address during the inaugural session of the workshop on 17.12.2017

Dr S K Tamotia, former CMD, NALCO addressing delegates during the inaugural session of the workshop on 17.12.2017

Presentation of memento to Mr Deepak Mohanty by Mr B K Mohanty, Advisor, SGAT

Presentation of memento to Dr S K Tamotia by Prof O N Mohanty, Vice-President, SGAT

Mr Deepak Mohanty & Mr Sanjay Pattnaik, Chair Persons of the 1st Technical Session of the workshop on 17.12.2017 with Mr B K Mohanty

Dr V P Upadhyay deliberating during the 1st Technical Session of the workshop on 17.12.2017

Dr T N Venugopal being presented a memento by the Chair Persons of the 1st Technical Session during the workshop on 17.12.2017

Sri Ashok Parija, President, Odisha High Court Bar Association and Sri Sudhakar Adhikaree, Senior Resource Consultant Chair Persons of the 2nd Technical Session during the workshop on 17.12.2017

Dr K Mahanta deliberating during the 2nd Technical Session of the workshop on 17.12.2017

Mr B K Mohanty, Mr A B Panigrahi, Dr T N Venugopal and Mr S K Mohanty on dais during the valedictory session of the workshop on 17.12.2017

Prof O N Mohanty, Mr S K Mohanty, Dr S C Mahala and Mr T Mohanta on dais during the AGB meeting on 17.12.2017

Participating members during the AGB meeting on 17.12.2017

Participating members during the AGB meeting on 17.12.2017

Dr V P Upadhyay receiving SGAT Lifetime Achievement Award from Mr B K Mohanty during the AGB meeting on 17.12.2017

Mr Subhajyoti Das receiving SGAT Award of Excellence from Dr S K Tamotia during the AGB meeting on 17.12.2017

Dr Lopamudra Panda receiving Sitaram Rungta Memorial Award from Mr R N Padhi during the AGB meeting on 17.12.2017

Mr Jayanta Kumar Nanda receiving the H H Read Memorial Gold Medal Award from Prof Dr Satyananda Acharya during the AGB meeting on 17.12.2017

Dr Satyabrata Nayak receiving B C Patnaik Memorial Award from Mr G S Khuntia during the AGB meeting on 17.12.2017

Prof Dr Prem Prakash Singh receiving the Best Paper Award on behalf of Dr Devananda Beura from Mr Sishir Chandra Rath, former DG, GSI during the AGB meeting on 17.12.2017

Prof Dr Omkar Nath Mohanty declaring the Election Results for the Executive council for the term 2017-19 during the AGB meeting on 17.12.2017

Punya Pratyusha Sethi and other Gold Medal Winners during the Valedictory Session of 11th IESO at Nice, France on 30th Aug 2017

News about Members

- Dr D P Mishra has been promoted to the position of Associate Professor in the Department of Mining Engineering at IIT (ISM), Dhanbad since June, 2017.

- Dr.B.M.Faruque, on invitation by IGCP 639/UNESCO, participated in the Summer School in Estonia, on Holocene sea level changes, Isostatic compensation, the Baltic Sea and Stone Age settlement on its shores. The field oriented Summer School was organised by University of Tartu, Estonia, during August 21-26, 2017. Besides Litorina palaeolagoon at Tolkuse, the programme included the varying levels of palaeoshorelines due to glacio-eustasy and isostatic compensation in the Estonian islands and Kaali Meteorite Impact Crater.

- Prof. K C Sahu, former Professor in Department of Earth Sciences, IIT-Bombay has published a book titled “Environmental pollution Societal impacts and Earth matters”. The purpose of this book is to arouse deep understanding and insight into various environmental issues of our fragile planet.

- Dr S N Patro, President, Odisha Environmental Society was felicitated as 'Senior Scientist of the State 2016' by Odisha Bigyan Academy, Science & Technology Department, Government of Odisha on 23rd August 2017.

- Sri G S Khuntia, former ED, SAIL was elected as Chairman of MGMI-Bhubaneswar on 9 September 2017.

- First edition of a book titled “Mineral Exploration: Practical Application (Springer Geology)” authored by Prof. G S Roonwal (Hon. Visiting Professor, Inter University Accelerator Centre, New Delhi) was published during the month of October 2017. The book introduces essential concept of mineral exploration, mine evaluation and resource assessment of the discovered mineral deposit to students, beginners and professionals.

- Dr D S Rao, Sr. Principal Scientist & Prof., AcSIR, Mineral Processing Department, CSIR-IMMT, Bhubaneswar was awarded with R.P. Bhatnagar Award by MGMI, Kolkata during their Annual General Body Meeting held on November 10, 2017 at Kolkata.

- Dr. B.K. Mohapatra, Former Chief Scientist, CSIR-IMMT, Bhubaneswar and visiting Professor of Geology, Ravenshaw University received Dr. J. Coggin Brown Memorial Gold Medal for Geological Sciences for 2016-17 from MGMI.

New Members

840 **Dr Smruti Ranjan Panda**
Dy. Manager (Mining & Geology)
Refractory Division
OCL India Limited
Rajgangpur – 770017
Sundergarh
Odisha

841 **Mr Saroj Kumar Patnaik**
Dy. General Manager (Mines)
NALCO,
Qr. No. D-82, Sector-III
At/Po: Damanjodi – 763008
Koraput, Odisha

842 **Ms Pallishree Prusti**
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Bhubaneswar-751013
Odisha

843 **Mr Sachida Nanda Sahu**
Scientist,
Mineral Processing Department
CSIR-IIMT,
Bhubaneswar-751013
Odisha

844 **Mr Bhuneswar Kumar**
Asistant Manager (Geology)
Essel Mining & Industries Ltd.
Koira Iron Ore Mine,
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845 **Mr Rajesh Kumar Patel**
Manager (Mines),
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846 **Mr Tonmoy Kundu**
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847 **Dr Arijit Barik**
Senior Geologist,
Geological Survey of India,
State Unit: Odisha,
Unit-8, Nayapalli,
Bhubaneswar-751012
Odisha

848 **Mr. Deepak Kumar Sahu**
Scientist, Mineral Processing Dept.
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Bhubaneswar-751013
Odisha

849 **Mr. Rajendra Kumar Ghadei**
Sr. Geologist
Geological Survey of India
Unit-8, Nayapalli
Bhubaneswar-751012
Odisha

850 **Mr. Purusottam Dandia**
Assistant Manager-Geology
Utkal Alumina International Limited,
Hindalco Industries Limited
At/P/O. Pallahara,
Dist. Angul, Odisha
PIN: 759119

851 **Mr Bijan Mohapatra**
Former DGM,
Rourkel Steel Plant, SAIL,
A/77, Sahid Nagar,
Bhubaneswar-751007

Obituary

Ramdas Agrawal
(1937 - 2017)

Ramdas Agarwal was a very important personality in the Mining Industry, and had immense contributions in the development of chromite mining of Baula sector. He was a very senior political leader and Member of Parliament (Rajya Sabha) for three terms. He was Rajasthan State President, National Treasurer and National Vice President of BJP.

Born on 17.3.1937, he left for his heavenly abode on 26.1.2017.

We deeply mourn his death and express our sincere condolences to the bereaved family and pray for his soul to rest in peace.

SGAT Family

Obituary

Ajit Kumar Patnaik
(1933 - 2017)

Ajit Kumar Patnaik, a prominent mining engineer, graduated from BHU, and served coal industry after joining National Coal Development Corporation (NCDC), the only central PSU in coal sector in India which later formed a part of Coal India Limited. He contributed to growth in various coalfields including WCL, CCL, BCCL, ECL, SECL and MCL. He developed the Bhubaneswar office under MCL. He retired from service in 1996 from MCL as CGM.

Born on 21.6.1933, this great Mining Engineer, left for his heavenly abode on 10.6.2017.

We express our sincere condolences to the bereaved family and pray for his soul to rest in peace.

SGAT Family

Obituary

P S R Reddy
(1953 - 2017)

P S R Reddy had obtained his B.Tech (Chemical Engg) in 1976 from Andhra University and M.Tech from IIT Kharagpur in 1978. He was an outstanding scientist, a wonderful person, and a perfect Team Worker, who had always put IIMT and its Mineral Processing Department, where he had served gloriously for 35 years, above himself.

Born on 1.7.1953, this great Mineral Engineer, left for his heavenly abode on 22.7.2017.

We express our sincere condolences to the bereaved family and pray for his soul to rest in peace.

SGAT Family

Obituary

K N Adhikari
(1949 - 2017)

K N Adhikari had his B.Sc (Geology) from Khallikot College, and later had his M.Sc (Geology) in 1971, from Ravenshaw College.

After a brief association with Public Health Engineering Department, Sambalpur, he had joined GSI in 1974 from where he had superannuated as Director in 2009. He had noteworthy contributions to the exploration and development of Chromites, Bauxites, Graphite, Limestones in Odisha and Multi Metal occurrences of Umpritha Valley, Meghalaya. His map compilation works in GSI are widely appreciated today.

Born on 3.3.1949, this diligent and very efficient Geologist, left for his heavenly abode on 29.7.2017.

The members of SGAT express their sincere condolences to the bereaved family and pray for his soul to rest in peace.

SGAT Family

Obituary

Dr. R P Das
(1945 - 2017)

Dr. R P Das was a metallurgical engineer, having great core competency in extractive metallurgy. He was very closely associated with development of several industrial processes, to recover copper, nickel, cobalt and zinc. His pioneering work and leadership efforts in finding processes for recovery of Nickel from the laterites of Sukinda Valley are very highly acclaimed. He had guided many Ph.D programmes of IIT Kanpur, IIT Kharagpur and Andhra University in Metallurgical and Chemical Engineering. He was on the editorial board of the prestigious "Hydrometallurgy" for more than 20 years.

Born on 1.11.1945, this scientist-par-excellence of IIMT Bhubaneswar, left for his heavenly abode on 12.12.2017.

We deeply mourn his death and express our sincere condolences to the bereaved family and pray for his soul to rest in peace.

SGAT Family

➢ SUBMISSION OF PAPERS FOR SGAT BULLETIN (Instruction to Authors)

Research papers, review articles, short communications, announcements and letters to editors are invited on topics like geosciences, mineral exploration, mining, materials science, metallurgy, mineral industry and trade, mineral economics, environment, education, research and development, legislation and infrastructure related to mining, mineral policy and mineral development planning.

Submission of manuscript implies that the same is original, unpublished and is not being considered for publication elsewhere. Two copies, complete in all respect (with copies of figures and tables) are required to be submitted. Originals of figures and tables should be enclosed separately. Each manuscript must accompany a soft copy of the entire material prepared in Microsoft Word. The figures, if any, may be submitted in JPEG/ TIFF/ BMP format. Both the text files and figures may be written on a CD/DVD and should be submitted with the manuscript. The copies of manuscripts, strictly in accordance with the instructions to authors given below may be sent to the editor of the bulletin.

Journal Format: **A-4 size**
Language: **English**

Manuscripts: Manuscripts should be computer typed in double spacing with wide margins in one side of A-4 size paper (size 12 point Times New Roman font). The title page should include the title of the paper, name(s) of author(s) and affiliation(s). The title should be as brief as possible. An informative abstract of not more than 500 words is to be included in the beginning. Not more than 5 key words are to be listed at the end of the abstract. Text of research papers and review articles should not exceed 4000 words. The short communication is for quick publication and should not exceed 1200 words.

Headings: Different headings should be in the following format.

(a) Title: Centrally aligned, bold, capital
(b) Author(s): Centrally aligned, short name, bold, first letter of all words capital followed by communication address (Not Bold, Italic)
(c) Abstract: Justified alignment, italic, bold heading
(d) Key words: Justified alignment
(e) Primary heading: Left aligned, bold, capital
(f) Secondary heading: Left aligned, first letter of each word capital
(g) Tertiary heading: Left aligned, first letter of first word capital
(h) Acknowledgements: Left aligned, bold, first letter capital
(i) References: Left aligned, bold, first letter capital
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Illustrations: All illustrations should be numbered consecutively and referred to in the text. They should confirm to A-4 size and carry short captions. Lettering inside figure should be large enough to accommodate up to 50% reduction. One set of hard copy of all figures (either tracing in ink or laser prints) should be provided in a separate envelope marked "Original Figures". Photographs should be of good quality with excellent contrast, printed on glossy paper. Colour photos are acceptable, provided the author(s) bear the cost of reproduction. Figure captions should be provided on separate sheet.

Tables: Each table must be provided with a brief caption and must be numbered in the order in which they appear in the text. Table should be organised within A-4 size and should be neatly typed for direct reproduction. Tables will not be typeset by the printer, so their clarity and appearance in print should be taken into account while the author(s) prepare(s) them. Use of 10 points Times New Roman/Arial Font for table is recommended.

References:

(a) References in the text should be with the name of the author(s) followed by the year of publication in parenthesis, i.e. Patnaik (1996); Patnaik & Mishra (2002); Nayak et al. (2001)

(b) Reference list at the end of the manuscript should be in alphabetical order, in the following format: Sehgal, R.K. and Nanda, A.C. (2002) Paleoenvironment and paleoecology of the lower and middle Siwalik sub-groups of a part of North-western Himalayas. Jr. Geol. Soc. Ind, vol. 59, pp. 517-529

(c) Articles from the books should follow the format given below:

Windley, B.F. and Razakamanana, T. (1996) The Madagascar – India connection in a Gondwana framework. (In Santosh, M. and Yoshida, M. Eds.)

The Archaean and Proterozoic terrains of South India within East Gondwana. Gond. Res. Group Mem. No.3, Field Sci. Publ., OSAKA, pp. 25-37

(d) Books should be referred to as: Sengupta, S.M. (1994) Introduction to sedimentology. Oxford and IBH Publ. Co. Pvt. Ltd., New Delhi, 314 pp.

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Manuscripts strictly confirming to the above format should be mailed to General Secretary, Society of Geoscientists and allied Technologists, Plot No. ND-12 (P), VIP Area, P.O. IRC Village, Bhubaneswar-751015 (sgatodisha@gmail.com). Manuscripts not confirming to the format of the journal will be returned.

All the manuscripts confirming to the standard format of the bulletin will be reviewed by specialist referees before publication.

Page proofs: One set of page proofs will be sent to the corresponding author, to be checked for typesetting only. No major changes are allowed at the proof stage. Proof should be returned within three days.

Reprints: 10 free reprints of each published article will be supplied to the corresponding author. Additional reprints can be ordered through payment at the proof reading stage.

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