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Implication of SD-PAMs

Geographic Information System

Highlights

Ore Minerals Assemblages

Carbon Sequestration Ecosystem

Discovering Thoughts, Inventing Future

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Contents of the Issue

i. Copyright Notice
ii. Editorial Board Members
iii. Chief Author and Dean
iv. Contents of the Issue

1. Geographic Information System (GIS) in Mapping of Mine Suspected Area in the Republic of Serpska. *1-4*
2. Implication of SD-PAMs In Nigeria. *5-9*
3. An Assessment of Carbon Sequestration Ecosystem Service in the Forests of Doon Valley, Western Himalaya, India. *11-19*
4. Manganese Ore Minerals Assemblages and Mineral Paragenesis with the Help of Ore Petrography and XRD Studies of Balaghat District, (M.P.) India. *21-34*

v. Fellows and Auxiliary Memberships
vi. Process of Submission of Research Paper
vii. Preferred Author Guidelines
viii. Index

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Geographic Information System (GIS) in Mapping of Mine Suspected Area in the Republic of Serpska

By Tatjana Baroš & Tatjana Stojanović
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Abstract- Geographic Information System (GIS) is a computing system to capture, store, manipulate, analyze, manage, and represent all types of geographical data. GIS systems are used in cartography, so that the simplest explanation of GIS was merging of cartography and database. There is almost no human activity related to a geographical territory, and the whole planet, which could not be improved by using an optimized GIS system. GIS allows efficient prediction and managing of resources to protect the environment. GIS technology provides public safety and the ability to manage and analyze large amounts of information. In the Republic of Srpska, as well as the whole country there are still a large number of mines from the Civil War (1992-1995). This paper describes the application of GIS and mapping the mine suspected areas, and the ability to facilitate consideration of the surface displacement due to severe flooding which occurred in the Republic of Serbian and region on May 2014, taking into account that the largest concentration of mines from the war was just through the length of the flooded river, which is the risk and responsibility to the Republic of Serbian and the states that border.

Keywords: GIS, environmental protection, mine suspected area, flood in.

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Tatjana Baroš [α] & Tatjana Stojanović [σ]

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I. Introduction

Geographic information system (GIS) is a computer system designed to capture, store, manipulate, analyze, manage, and present all types of geographic data. The acronym GIS is sometimes used for geographic information science or study of geospatial information related to academic discipline or career working with geographic information systems and a major domains within the wider academic discipline of geoinformatics. [1] The simplest explanation is that GIS is the merging of cartography and GIS database technologies. GIS systems are used in cartography, remote sensing, surveying, management utilities, photogrammetry, geography, urban planning, management of emergencies, navigation and localized search engines. GIS applications are tools that allow the user to make interactive queries (user request), analyze spatial information, edit data, maps, and presents the results of all these operations. Geographic information science is the science which are basically geographic concepts, applications and systems, studied and validated at various universities. [2] In this paper we show the use and application of GIS in mapping mine suspected areas on the territory of the Republic of Srpska.

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II. About the Geographic Information System

For the application of GIS it is necessary a map which displays the data. Site map should be of the highest quality, and for the quality map it is believed that is the map wich is exact placed in the exact geographical coordinates. Coordinate Reference System (CRS) can be explained as a coordinate system that is associated with the Earth with geodetic date [2]. CRS can be geodetic coordinate system where the positions are defined by geographic longitude and latitude. In the most cases, is using of the projected coordinate system where the coordinates are transferred to the plane using the Map projections. Within one country can be a number of different coordinate systems (NGO, MG17, GK6, UTM34) in use. [3] In the Republic of Serbian WGS84 -UTM zone 34 coordinate reference system is using. [4] The definition of the geographic coordinate system is practically reduced to definition of the two mathematical models. The first is a mathematical model of the Earth's sphere or its part that we are trying to represent by mapping. This mathematical model (with particular reference point on the sphere) in geo-science and so. space industry is called a date. Given that the main task in creating maps is that the image of a terrain with curved surfaces set on the plane, it is not enough just to have a model of the Earth. The second mathematical model that is directly responsible for this "setting on the plane" is called projection. There is a huge number of dates and projections in use. Practically every country in the world has its own date and projection, and some of the country have several dozen. Traditional GIS packages are programs that work with maps in vector format. In addition, they have the above-mentioned geographic coordinate system through which the position of certain objects on the map associated with their actual position. This feature of GIS system is called georeferencing and is the essence of the GIS idea. Without georeferencing, GIS systems would be kept to a regular (electronic)

map, not much more useful than their "paper ancestors." [4] If we use the whole maps, all of data on the map (coordinates, date created, projection, with maps etc.), are later used in the process of georeferencing. Given that the geographical data in a GIS are geographicly oriented and defined by geographic coordinates, it is necessary to present a data by thematic layers. [5] In addition to geo-referencing, as well as in any other information system, the most important feature of GIS systems are, of course a database. The ability of GIS to manage a database, to complement and to searches database by using vector maps, objects on that maps or simply based on the given coordinates is actually a basic measure of its functionality. In order to be able to use geographic information system it is necessary to ensure appropriate software- (a) commercial: Autodesk (MapGuide), Cadcorp, Intergraph (GeoMedia, GeoMedia Professional, GeoMedia WebMap, ERDAS IMAGINE, ESRI (ArcView 3.x, ArcGIS, ArcSDE , ArcIMS, ArcWeb) Idris, MapPoint, etc., and (b) non-commercial: GRASS, MapServer, Chameleon, GeoNetwork opensource, GeoTools, gvSIG, ILWIS, JUMP GIS, OpenLayers, PostGIS, Quantum GIS TerraView etc ... [6]

III. The Application of GIS in Protection of Environmental in the Extreme Situations

There is almost no human activity that is linked to some territory, and even the entire planet, that could not be improved by using optimized GIS system. [5] GIS is a computer technology that connects geographic data with other types of data in order to create analytical framework for understanding and visualize spatial relationships. GIS enables efficient forecasting and management resources before, during and after the crisis. [7] The geographical information is a key component of any information system that is designed to support social or environmental analysis or decision-making. GIS is a computer technology that is often defined as an integrated set of tools and methodologies for collecting, storing, editing, integration, analysis and visualization of spatial referenced data. [8] In the geographic area all the social and ecological processes are occuring. From this implies that the location is the main dimensions for reviewing all of environmental and social factors. GIS linking geographic informations with other types of data in order to create analytical framework for understanding and visualizing spatial relationships. Using GIS everyone can share information and computer-generated maps in one place. GIS provides a mechanism for centralization and visualization of critical information in emergencies. GIS allows the user to combine data sets. GIS technology provides public safety and the ability to manage and analyze large amounts of information. Data can be stored in a geographic database and can be used to visualize spatial relationships and analyze trends to track a phenomenon. Computer-generated maps can be shared over a network or the Internet with multiple agencies to coordinate efforts in order to increase the funds. Operation of overlapping layers on the map allows analysts to calculate new values for places based on multiple attributes or layers of data to identify and display the locations that meet certain criteria. GIS is used for monitoring, surveillance, data collection, management in the field, more efficient data analysis, policy analysis and planning, rapid sharing of information. [7] GIS uses detailed digital maps, satellite images and computer models to determine where it is necessary to react. Application of GIS allows quantify and summarize data in a simple way. Spatial analysis involves three basic steps: preparation of an appropriate model, its proper visualization and analysis of data from a simple map to statistical models. To do this all you need is a lot of information immediately in the real world. Analysis and modeling (events, actions, reactions) depend on the positioning of the exact coordinates in the real world. Geospatial technology can be used for designing and managing database systems, systems for monitoring, controlling and reporting the performance of spatial queries, data compression, visualization and analysis, data modeling, map production, dissemination of information needs. [7]

IV. Application of GIS in Mapping a Mine Suspected Areas in the Republic of Srpska

As a result of the civil war (1992-1995), Bosnia and Herzegovina is still one of the most mine-contaminated countries in South-Eastern Europe, taking into account that a large number of unexploded ordnance deployed in the surrounding rural areas. By the end of the conflict in 1995, nearly 600601 people were killed as a result of explosive remnants of war remaining. Nearly 20 years after the war in Bosnia and Herzegovina, over 200,000 mines and other ordnance are still located throughout the country. Equally it is a number of potential victims. Mines are still distributed to as many as 1340 km^2. A large investigation of minefields was done. In doing so, their expertise gave the soldiers who had taken part in setting up mines. So they could fence dangerous areas to prohibit access to the population. Then began a systematic search of minefields and mine clearance. There are different methods of detection mines- robots, rats, bees (which can learn to recognize the scent of explosives), or even genetically modified plants. Manual search is still the most responsible way of clearance. Mine often consist of plastic so metal detectors do not help much. Over the minefield drives digging machine, and so triggers an explosion of mines laid in its territory. The using of GIS mapping in mine suspected areas provides: efficient

management of mine suspected areas, better protection, interactive access and manage (query, update, delete, add, connect) with databases, statistical data analysis, presentation of digital maps (maps on display computer screen and printing), viewing of multimedia data (establishing links between data on a map and photos or analysis and modification of existing data), display and printing of reports, etc. [3]. GIS can be combined with other systems which is another justification of using GIS application systems. Although geographic information system offers rich opportunities in the manipulation of input data, processing and generating output data, it has certain drawbacks, both in 3D modeling and in the visualization of data. On the other hand, object-oriented software packages that are designed for modeling and visualization showing those deficiencies that constitute the major advantages of GIS. Using the coupling of these two systems is achieved by effective use of modern planning techniques. [3]

a) *Mapping the movements of mine suspected areas due to heavy flooding in the Republic of Srpska and region*

As already mentioned, a large number of mines left over from the civil war are still located on the territory of the Republic of Serbian and BiH. The highest concentration of mine suspected areas is along the border rivers, as well as the inter-entity boundary line and the state border. Due to the severe flooding which occurred in Bosnia, Croatia and Serbia on the May 2014, there was a possible displacement of mines, which were carried by the flooded river. United Nations Development Programme (UNDP) and the Mine Action Centre (MAC) emphasize that the record floods which occurred in the Balkans may increase the risk of mines in Bosnia and Herzegovina. UNDP since 1996, is actively working with the authorities in cleaning, recording and marking minefields. So far cleared over 26 960 km^2 of mine contaminated areas, however, nearly two-thirds of 1230 km^2 was covered by floods and over 2000 landslides was activated. According to the Mine Action Centre BiH, there is more than 100,000 mines. Floods triggered mine and stolen signs which were labeled dangerous areas. Some of the recorded cases of explosion of mines that are shifted by floods have occurred in the area of Brcko District in the north of the country; Srebrenica and Bratunac. Also, the mine threat is largely present in the river basins of Bosnia, prevent, Usore and cranks. In Bijeljina, reported finding mines in six locations in the city and suburbs. Thus, after the withdrawal of water at three points in the Prijedor area located explosives devices. According to the BHMAK's, whose teams have also arrived in places that were affected by the weather woes, mine is the most vulnerable area of Doboj, Maglaj, lead, and the Bosanska Posavina, Tuzla and Una-Sana Canton. Flow Mine is possible Sava and Danube to Romania and even Bulgaria. Experts claim that the mine could stop by the turbines of hydroelectric power plants.

V. Conclusion

In order to manage natural resources in a sustainable manner it is required accurate and timely information to make action to changes in field on time. For this reason, it is necessary to establish a system that will integrate all relevant data to achieve the stated goal. In a word it should formed a system that would be able to simply search database as well as the ability to display imformacija through colors and symbols. To achieve the above requirements imposed by the simple answer, and it is the application of GIS in mapping mine suspected areas, for better monitoring, visualization, planning demining activities as well as easier and faster updates. On the basis of creating layers, in GIS it is possible to make a layered representation of data (which are stored in shape files). Figure 1 shows the territory of the Republic of Srpska divided by municipalities with mine suspected areas. Here are added two shape files, one of which represents a mine suspected area (highlighted in red) and the other municipalities of Republic of Srpska (shown in pink color). In this section of two shape files, it is presented the RS territory affected by mines. On the detail of the R = 1: 250 000 shown is part of the territory of the municipality of Doboj, which is the most damaged in the floods in May 2014 with a topographical map as a base. The mine suspected area is marked, and it is assumed that the water is shifted mine. Here, using GIS can track, update and manage mine suspected areas on the territory of RS. The said territory is shown and mapped in ArcGIS.

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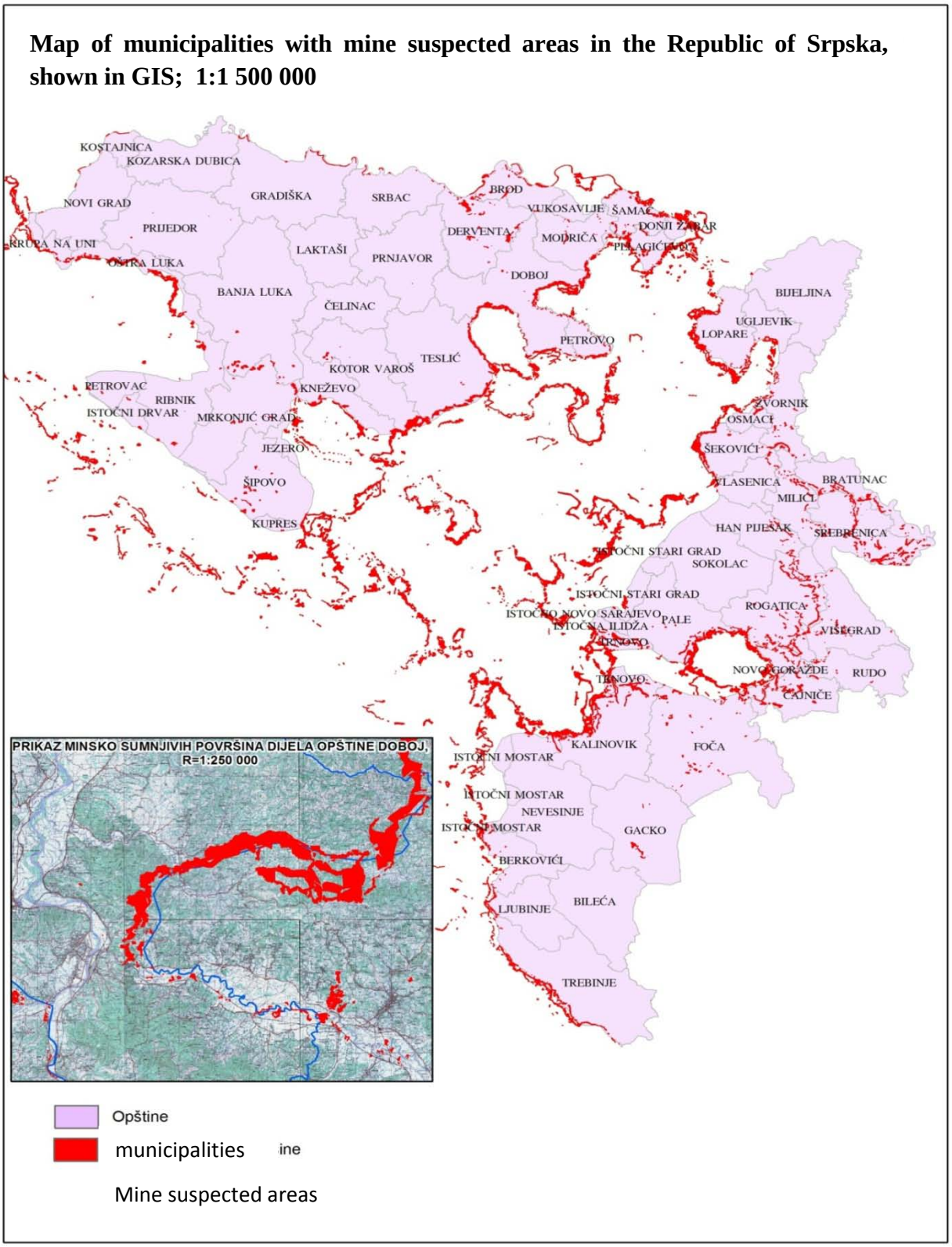
8. Meade and Earickson 2000, p.461; Gatrell 2002, p.72

Attachments

Figure 1 : Overview map of municipalities with mine suspected areas in the Republic of Srpska, shown in GIS



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Implication of SD-PAMs In Nigeria

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Abstract- Sustainable Development Policies and Measures (SD-PAMs) have been identified as a possible means through which developing nations can contribute to the global climate change mitigation and adaptation effort. Nigeria being an oil producing nation derives up to 70% of her revenue from the petroleum industry but the gas sector has not be given the necessary attention until recently resulting to both economic and environmental lost via gas flaring or what is called fugitive gas. This natural gas being flared has the potential of putting to an end the epileptic electricity situation in the country, if well harnessed and managed. Nigeria ranks second in the World in terms of total volume of gas being flared, but according to World Bank 2007 report, there was a remarkable reduction of about 10 BCM of gas flaring in Nigeria between 1996 and 2005, about the same period that Nigeria Liquified Natural Gas (NLNG) and some Independent Power Project that utilizes natural gas was commissioned. The NLNG has being a source of revenue for government and provides jobs for the teeming youth of the restive Niger-Delta area. Strong political in the form of sustainable development policies and measures will to put an end to gas flaring and well structure national gas master plan that focus on meeting local demand is still required for optimum economic and environmental gains to be achieved.

Keywords: *adaptation, fugitive gas, gas flaring, mitigation, sustainable development policies and measures.*

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Keywords: adaptation, fugitive gas, gas flaring, mitigation, sustainable development policies and measures.

I. Introduction

SD-PAMs is an approach to development tailored to boost environmental concerns based on government policies and measures, the policies might be fiscal or legislative. The pivotal of such policies and measures are economic and physical development but consequential environmental gains accruing from such policies are worthy of note in global context of climate change mitigation effort. However, minimum developmental indices that relate to the populace must be met as the yardstick in evaluating the success or otherwise of the policies and measures.

Nigeria environmental policy identified key sectors requiring integration of environmental concerns and sustainability with development. It presented specific guidelines for achieving sustainable development in the following fourteen sectors of Nigeria's economy: Human Population, Land Use and Soil Conservation, Forestry, Wildlife, Water Resources Management, and Protected Natural Areas, Marine and Coastal Area Resources, Waste Management and Sanitation, Toxic and Hazardous Substances, Mining and Mineral Resources, Energy Production, Agricultural Chemicals, Air Pollution, Noise in the Working Environment, Settlements, Recreational Space, Monuments, Green Belts and Cultural Property. SD-PAMs has implications on most of these sectors, but this paper considers mainly the implications of SD-PAMs in Energy production and management (gas flaring)

Nigeria being the most populous Africa nation with its fastest emerging economy, industries and Megapolitican cities has electricity shortage challenge and this has been described as vital of most developmental deficiency in the country. The Access to electricity (percentage of population) in Nigeria was 50.60% in 2009 according to a World Bank report, published in 2010 and less than 50 percent as at 2014. Nigeria has sufficient natural and renewable resources that can be channeled toward electrical power generation such as coal, water, solar, wind, biomass and natural gas. But not until recently, emphasis was placed both on hydro and thermal power plant with natural limitation of fluctuation in water level of the dams. Other electricity generating resources remain under-utilized while some are being wasted such as natural gas or fugitive gas resulting in economic loss, human resource wastage and environmental degradation.

Nigeria's oil wealth has been exploited for close to 50 years. But while oil companies have profited from the resource, local communities in the oil rich but conflict-ridden areas live with the daily pollution caused by non-stop gas flaring or better term fugitive gas - where the gas associated with oil extraction is burnt off into the atmosphere. Gas flaring is the burning of natural gas that is associated with crude oil when it is pumped up from the ground. In petroleum-producing areas where insufficient investment was made in infrastructure to utilize natural gas, flaring is employed to dispose of this associated gas.

Nigeria's proven oil reserves are estimated to be 36 billion barrels; natural gas reserves are well over 100 trillion cubic feet (U.S. Dept of State). According to World Bank 2007 report, Nigeria flares more gas than any other country in the world except Russia, in terms of the total volume of gas flared. In 2011 Nigeria's volume of gas flared was equivalent to one-seventh of total gas

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flaring in world ie 31.07 $MTCO_2$-eq as against 224.80 $MTCO_2$-eq as shown in table 1 below. Globally, the volume of gas flared between 1996-2006 (during which time awareness of the detrimental impact of flare emissions on the global climate grew) remained relatively constant, ranging between 150-170 billion cubic meters. Nigeria's share of the total volume is approximately 24.1 billion cubic meters of gas. (By comparison, the U.S. flared 2.8 billion cubic meters during the same time period) and that had continue to rise on the business as usual scenario as also reported by the World Resource Institute 2015. Although Nigeria's emission by gas and Subsector of this fugitive gas as GHGs was 0.28 and 57.33 $MTCO_2$-eq and 722.38 and 2,523.00 $MTCO_2$-eq as against the World's respectively (Ojekunle et. al., 2014)(See table 1).

Table 1 : Nigeria's Emission in relative to World global emission as at 2011

Parametre	Sector/Sub Sector	Nigeria $Mtco_2$-Eq	World $Mtco_2$-Eq
Total CO_2	Total CO_2	183.92	32,127.54
Total GHGs	Excluding LUCF	324.51	43,645.77
	Including LUCF	496.13	45,720.46
GHGs by Gas	CO_2	83.93	32,127.84
	CH_4	205.52	7,245.63
	N_2O	34.52	3,550.22
	F-Gas	0.28	722.38
GHGs Emission by Sector	Energy	158.50	33,338.44
	Industrial Process	n/a	2,588.54
	Agriculture	100.68	6,031.15
	Waste	65.04	1,480.97
	LUCF	171.63	2,074.70
	Bunker	2.87	1,044.22
GHGs Emission by Sub-Sector	Heat/Electricity	18.11	14.542.27
	Manufacturing/Construction	4.32	6,489.75
	Transportation	23.58	5,850.32
	Other Fuel	53.16	3,958.37
	Fugitive Emission	57.33	2,523.00
CO_2 Emission by Sub-Sector	Heat/Electricity	18.11	14,542.27
	Manufacturing/Construction	4.32	6,489.75
	Transportation	23.58	5,850.32
	Other Fuel	53.16	3,212.58
	Fugitive Emission	31.07	224.86

Source: World Resource Institute – CAIT 2014, Global Journal of Human Social Science: B (2014)

Gas flaring not only wastes a potentially valuable source of energy (natural gas), it also adds significant carbon emissions to the atmosphere as shown in table 1. Moreover, flaring combustion is typically incomplete, releasing substantial amounts of soot, carbon monoxide, NOx compound and ozone which contribute to air pollution problems. An array of technologies to capture i.e carbon capture and storage/sequestration or use the associated natural gas exists as viable alternatives to flaring. It can be re-injected, which boosts oil production and contains the gas, transported via gas pipelines, converted to liquids that can be more readily transported or used on site. In most European countries, 99 per cent of associated gas is used or re-injected into the ground. But in Nigeria, inspite of the regulations that was introduced 20 years ago to outlaw the practice, associated gas flaring is on the increase, causing local, regional pollution and contributing to climate change.

II. Literature Review

Winkler *et al.*, 2002 reported the use of "sustainable development policies and measures" (SD-PAMs) as been proposed for the developing countries as a possible type of action or commitment in the post-2012 framework . The definition of SD-PAMs remains open, one proposed definition (Winkler *et al*., 2002) suggests that they should be domestically driven, could cover diverse approaches in many different sectors and have a development focus. Thus, SD-PAMs include a large range of national or sectoral policies with a direct impact on GHG emissions such as increasing electrification rates, improving energy efficiency or encouraging re/afforestation activities. This definition could also encompass policies and measures with a more indirect climate benefit, such as increasing the availability of information/training and support on climate change or modifying urban planning procedures and policy to reduce the negative impact of urban developments on local, regional conditions and GHG emissions.

According to JINN, some experts believe Nigeria's gas flares are the single largest source of greenhouse gasses in Africa, south of the Sahara." Flaring gas is illegal in Nigeria but it is difficult to control

because of lack of technical support. The first order by Nigerian head of State related to flaring was in 1969 when President Yakubu Gowan ordered that within 5 years of set-up, a company must cease flaring. Through the Associated Gas Re- Injection Act Number 99 of 1979, the Nigerian government required oil corporations operating in Nigeria to guarantee zero flares by January 1, 1984. The Act allowed some conditions for specific exemptions or the payment of a fee of US $0.003 (0.3 cents) per million cubic feet, which increased in 1988 to US $0.07 per million cubic feet, and in January 2008 to US $3.50 for every 1000 standard cubic feet of gas flared. This is still considered meager and not a deterrent for companies, which find it easier to just pay the fine according to JINN but many company are still paying lip service to this law and payment.

According to the Nigerian National Petroleum Corporation (NNPC) in its quarterly petroleum information bulletin seen by BusinessDay, the nation flared 222.8 million standard cubic feet (mscf) of gas, during the period under review of *2012*, which if processed and exported, would have fetched the country about ₦99 billion and minimized the health and environmental hazards of gas flaring. A breakdown of the report showed that Chevron, Shell and ExxonMobil, accounted for 67 percent of total gas flared in the first six months of year 2012. Using the current international price of $2.83, this is equivalent to ₦67 billion ($424) in monetary terms. Chevron topped the company profile flaring 59.7 million standard cubic feet (mscf) out of 130.2 mscf produced, while ExxonMobil flared 56.6 mscf, out of 212.9 million. These are equivalent to ₦27 billion ($169 million) and ₦25 billion ($160 million) respectively. Leading operator, Shell which is the leading operator that runs Nigeria's liquefied natural gas (LNG) plant, flared 33.9 mscf, a relatively small part of the 414.3 mscf it produced which is equivalent to ₦15 billion ($96 million) of the ₦99 billion. While other Joint Venture Companies (33 mscf); production sharing contract (33 bscf); service contract companies (5 mscf), indigenous companies and marginal fields (2 mscf) accounted for the remaining 73 mscf of gas flared. (BusinessDay, 2012). Though the Nigerian government promised to enforce the ban they themselves set on flaring in December 31, 2008, they have not enforced the ban by fining the oil companies as promised. Instead they are attempting to delay the deadline yet again, with the backing of the oil industry, to 2012. In 2005 the federal High Court of Nigeria ruled flaring by Shell and the NNPC, with which Chevron jointly operates, illegal and a violation of the rights to life and dignity.

III. Materials and Methods

In presenting this paper, data were collected from report commissioned by World Bank and other Agencies and systematic review approach was used in presenting the facts. Most of the materials were sourced online archives. A systematic review is a literature review focused on a research question that tries to identify, appraise, select and synthesize all high quality research evidence relevant to that question (Wikipedia, 2013). Other sources which is important to this work is using a model known as Climatic Analysis and Indicator Tools (CAIT) produced by World Resources Institute beta 2.0, 2014 and was use to produced and compare results across countries as shown in table 1 and use for subsequent discussion.

IV. Results and Discussion

The gas sector holds significant potential. Nigeria has the 7th largest reserves in the world with significant scope for growth. The gas quality is high – particularly rich in liquids and low in sulphur. The pre-NLNG era was marked by fiscal incentives to stimulate demand focus on exports (LNG) as most promising source of demand; hence birth of an export oriented gas sector and absence of gas legal framework. All these resulted in sudden boom in demand from both domestic and export sectors and subsequent shift from demand to supply constrained.

Thermal generated electricity in Nigeria constitutes 76% while hydropower stations provide the remaining 24%. Most new power plants in Nigeria are power by natural gas which is the global trend e.g. Papalanto, Olorunsogo, Omotosho, Afam, Okapi, Omoku, Geregu, Obajana etc.

Natural gas, because of its clean burning nature, has become a very popular fuel for the generation of electricity. In the 1970s and 1980s, the choices for most electric utility generators were large coal or nuclear powered plants. However, due to economic, environmental and technological changes, natural gas has become the fuel of choice for new power plants built since the 1990s. In fact, the Energy Information Administration (EIA) estimates that between 2009 and 2015, 96.65 gigawatts (GW) of new electricity capacity will be added in the U.S. of this, over 20 percent, or 21.2 GW, will be natural gas additions

According to Bloomberg 2012 report natural gas is the cheapest option for new power generation, the largest U.S. wind-energy producer, NextEra Energy Inc. (NEE), has shelved plans for new U.S. wind projects next year and Exelon Corp. (EXC) called off plans to expand two nuclear plants. Michigan utility CMS Energy Corp. (CMS) canceled a $2 billion coal plant after deciding it wasn't financially viable in a time of "low natural-gas prices linked to expanded shale-gas supplies," U.S. gas supplies have been growing since producers learned how to use hydraulic fracturing and horizontal drilling to tap deposits locked in dense shale rock formations.

The cost, including construction, to produce one megawatt hour of gas-fueled electricity was $62.37

an hour in the third quarter of 2011, which was less expensive than coal, wind and solar generators, according to data compiled by Bloomberg.

The major challenge slowing down government stride to increases electricity power generation in Nigeria is irregular gas supply to most newly constructed power stations.

According to World Bank 2007 report, there was a remarkable reduction of about 10 BCM of gas flaring in Nigeria between 1996 and 2005, about the same period that NLNG and some Independent Power Project that utilizes natural gas was commissioned. The NLNG has being a source of revenue for government and provides jobs for the teeming youth of the restive Niger-Delta area. Better policies and measures on adaptive strategies in curbing gas flaring will go a long way to reduce health risk and consequent climate change. Focus should be on clean energy use and the less dependence on fuel regime and ability to on biomass production to sustain electricity generation.

In view of this, the government sustainable development policies and measure should aimed as enacting a comprehensive law or body of laws to provide a mechanism for achieving Nigeria's adaptation policy objectives, while Mainstreaming climate change adaptation into all existing and new National Development Plans and official Vision statements (such as *Vision 20:2020*). Mandate the Authority responsible for Climate Change to carry out the following functions: planning and setting priorities (including support for information and data collection), implementation, mobilization of resources, evaluation. Ensure that climate change adaptation is taken into account when drawing up the Countries's Annual Budget as well as creating an enabling environment for the organized private sector to invest in climate change adaptation, including business opportunities presented by climate change adaptation options. Strengthen the capacity of communities by providing information and technical know-how, facilitating access to micro-credit and other measures. Put in place a climate change adaptation and gas flaring communication and outreach strategy with the objective of enabling a level of understanding that will allow all stakeholders to participate actively in climate change adaptation. Carry out gender-sensitive research that will deepen our understanding of communities' awareness and vulnerability, and the status of community adaptation to climate change. The international bodies should of necessary provides technical support for research, monitoring and evaluation of the mainstreaming process in order to develop understanding of what contributes to its success.

V. Conclusion

The economic value of oil and gas investment in Nigeria's coastal and offshore areas is in the trillions of US dollars. This investment is at risk from the negative impacts of climate change which is a factor of gas flaring, including rising sea levels, heavy storms, floods, high winds and shoreline erosion. Climate change is also expected to negatively impact the already limited electrical power supply through impacts on hydroelectric and thermal generation. Service interruption is also expected to result from damage to transmission lines and substation equipment impacted by sea level rise, flash floods, and other extreme weather events. Climate change impacts resulting in increased fuel-wood scarcity will increase pressure on the remaining forest resources, resulting in further degradation of the environment and negative impacts on rural livelihoods.

There is need for comprehensive national gas plan that place priority on meeting the local demand rather than exportation. Also the newly drafted Petroleum Industry Bill that says, "Natural gas shall not be flared or vented after 31st December, 2012, in any oil and gas production operation, block or field, onshore or offshore, or gas facility," except under exceptional and temporary circumstances and that "Any licensee who flares or vents gas without the permission of the Minister in (special) circumstances shall be liable to pay a fine which shall not be less than the value of the gas" should be implemented with due diligence.

The study further recommend that companies should henceforth increased protective margins in construction and placement of energy infrastructure (i.e. higher standards and specifications). Undertake risk assessment & risk reduction measures to increase resilience of the energy sector. Strengthen existing energy infrastructure, in part through early efforts to identify and implement all possible 'no regrets' actions. Develop and diversify secure energy backup systems to ensure both civil society and security forces have access to emergency energy supply. And finally expand sustainable energy sources and decentralize transmission in order to reduce vulnerability of energy infrastructure to climate impacts

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An Assessment of Carbon Sequestration Ecosystem Service in the Forests of Doon Valley, Western Himalaya, India

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Abstract- The study focused on the carbon allocation and carbon sequestration ecosystem service provided by the forests of Doon Valley. 150 Quadrats were laid down to assess the biomass and carbon stocks and the carbon dioxide mitigation potential was estimated in each of the forest ranges (Barkot Range, Lachchiwala Range and Thano Range) of Dehra Dun Forest Division in Doon Valley, Western Himalaya, India. Carbon stock density varies from 13.39 Mg ha^{-1} in Scrub of Thano Range to 213.58 Mg ha^{-1} in Moist Deciduous Forest of Lachchiwala Range. Soil Organic Carbon Density ranged between 161.66 Mg ha^{-1} in Pure Pine Forest of Thano Range to 259.97 Mg ha^{-1} in Moist Deciduous Forest of Barkot Range. Thano Range has the carbon dioxide mitigation share of 37.29% while the Lachchiwala Range shared 35.37%. The Barkot Range contributed 27.34% of the Carbon dioxide mitigation. Various anthropogenic pressures from the villages at the forest fringes have the impact on the carbon stocks. Forests of Doon Valley have the potential to mitigate the climate change through proper and effective implementation of mitigation programmes. Reducing emissions from deforestation and forest degradation plus can be a vital programme that can be implemented to protect the forests of Doon Valley and assist in climate change mitigation.

Keywords: climate change, mitigation, carbon stocks, soil organic carbon, carbon dioxide equivalent, carbon sequestration.

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An Assessment of Carbon Sequestration Ecosystem Service in the Forests of Doon Valley, Western Himalaya, India

Mohommad Shahid [α] & Shambhu Prasad Joshi [σ]

Abstract- The study focused on the carbon allocation and carbon sequestration ecosystem service provided by the forests of Doon Valley. 150 Quadrats were laid down to assess the biomass and carbon stocks and the carbon dioxide mitigation potential was estimated in each of the forest ranges (Barkot Range, Lachchiwala Range and Thano Range) of Dehra Dun Forest Division in Doon Valley, Western Himalaya, India. Carbon stock density varies from 13.39 Mg ha^{-1} in Scrub of Thano Range to 213.58 Mg ha^{-1} in Moist Deciduous Forest of Lachchiwala Range. Soil Organic Carbon Density ranged between 161.66 Mg ha^{-1} in Pure Pine Forest of Thano Range to 259.97 Mg ha^{-1} in Moist Deciduous Forest of Barkot Range. Thano Range has the carbon dioxide mitigation share of 37.29% while the Lachchiwala Range shared 35.37%. The Barkot Range contributed 27.34% of the Carbon dioxide mitigation. Various anthropogenic pressures from the villages at the forest fringes have the impact on the carbon stocks. Forests of Doon Valley have the potential to mitigate the climate change through proper and effective implementation of mitigation programmes. Reducing emissions from deforestation and forest degradation plus can be a vital programme that can be implemented to protect the forests of Doon Valley and assist in climate change mitigation.

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I. Introduction

Ecosystem functions are the conditions and processes through which natural ecosystems and their constituent species sustain and fulfil human life (Daily 1997). Ecological services are those ecosystem functions that are perceived to support human welfare (De Groot 1992; Ehrlich & Ehrlich 1992; Barbier et al. 1994; Costanza et al. 1997; De Groot et al. 2002). Brown et al. (2006) described Ecosystem Services that are derived from the functioning of an ecosystem and are of direct value to humans.

Forests are very important ecosystems, delivering benefits that go far beyond the supply of timber i.e. fuel wood, fodder, food, bamboos, Non Timber Forest Products (NTFPs), carbon sequestration, climate amelioration, soil and water conservation, recreation, etc. Furthermore, forests play a key role in maintaining water quality, clean air, and help in regulating climate, floods, pollination, biological control of diseases, etc. thus providing various regulating services (Bahuguna and Bisht 2013).

Important climate-related functions of forest ecosystems are carbon sequestration and carbon storage, which create carbon stocks. The persistence and resilience of these carbon stocks as well as the continued ability of forests to absorb carbon dioxide from the atmosphere are significant factors in the role that forests can play in climate change mitigation (Díaz et al. 2009). A rapidly expanding interest in the ability of trees to sequester carbon has spawned numerous initiatives for forest conservation, regeneration and improved management.

Forests sequester and store more carbon than any other terrestrial ecosystem and are an important natural 'brake' on climate change. When forest are cleared or degraded, their stored carbon is released into the atmosphere as carbon dioxide (CO_2). The main carbon pools in forest ecosystems are the living biomass of trees and understorey vegetation and the dead mass of litter, woody debris and soil organic matter. Knowledge of the aboveground living biomass density is useful in determining the amount of carbon stored through photosynthesis in the forest stands. Thus, estimating aboveground forest biomass carbon is the most critical step in quantifying carbon stocks and fluxes from forests (Gibbs et al. 2007).

Soil carbon is an important determinant of site fertility due to its role in maintaining soil physical and chemical properties (e.g. aggregate stability, cation exchange capacity) (Reeves 1997). Soil stores 2 or 3 times more carbon than that which exists in the atmosphere (Davidson et al. 2000) as CO_2 and 2.5 to 3.0 times as much as that stored in plants in the terrestrial ecosystem (Houghton and Skole 1990). Land-use and soil-management practices can significantly influence Soil Organic Carbon (SOC) dynamics and C flux from the soil (Batjes 1996; Post & Kwon 2000). Spatially distributed estimates of SOC pools and flux are important requirements for understanding the role of soils in the global C cycle and for assessing potential biospheric responses to climatic change or variation (Schimel et al. 2000).

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Various workers have conducted the studies on ecosystem services (Haripriya 2000, 2003; Lead India 2007; Singh 2007; Singh and Das 2008; Gera et al. 2011; Bisht & Singh 2011). In this paper, we analyzed the carbon sequestration service provided by the forests of Doon Valley. Carbon Dioxide mitigation by the forests of Doon valley is worked out.

II. Materials and Methods

a) Study Site

The study was conducted in the three ranges (Barkot Range, Lachchiwala Range and Thano Range) of Dehra Dun Forest Division located in Doon Valley in the Southwestern part of the state of Uttarakhand, India. The word Doon represents the boulder valley that runs parallel to and between the lesser Himalayan range and the Shiwalik range. The Doon valley is located in the Shiwalik Himalayas, lying between latitudes 29°55′ and 30°30′ N and longitudes 77°35′ and 78°24′ E. It is about 20 km wide and 80 km long saucer-shaped valley with a geographical area of ca. 2100 km^2 (Figure 1) The area is bounded by the river Ganga in the east and river Yamuna in the West. The northern boundary is formed by Mussoorie hills whereas the Shiwalik mountains form the southern boundary of the valley. The Doon valley falls under the sub-tropical to temperate climate due to its variable elevation. The average maximum temperature for the Doon valley was 27.65°C and the average minimum temperature was 13.8°C, with average maxima in June (40.00°C) and average minima in January (1.80°C) in year 2010-11. The area received an average annual rainfall of 2025.43 mm. The region receives most of the annual rainfall during June to September, the maximum rainfall occurring in July and August.

b) Biomass Carbon Stock Assessment

50 quadrats of 10 × 10 m^2 were laid down randomly in each range of the entire study area. The height and diameter at breast height (1.37 m above the ground) of all the trees within the sampling quadrat were measured. The volume of the individual trees was estimated using the species specific volume equations (FSI 1996). The estimated volume of each tree was multiplied by its wood density to derive the stem biomass. Later, the bole biomass was multiplied by the biomass expansion factor (Haripriya 2000) to derive individual tree aboveground biomass. Aboveground biomass was used to calculate the Belowground Biomass by multiplying the value of aboveground biomass with the constant factor 0.26 (IPCC 2006). Aboveground biomass and belowground biomass were added to get the individual tree total biomass. The carbon contents was calculated by the multiplying the individual tree total biomass with the conversion factor 0.5 (IPCC 2006). The individual tree total biomass and carbon contents in a quadrat were summed to obtain total biomass and carbon storage in sampling quadrat. The mean total biomass and carbon were calculated by averaging the total biomass and carbon values in all sampling quadrats.

c) Soil Organic Carbon

Soil organic matter tends to concentrate in the upper soil horizons with roughly half of the soil organic carbon of the top 100 cm of mineral soil being held in the upper 30 cm layer (IPCC 2003). Therefore, we have collected the soil samples from the upper 30 cm layer. Forest floor litter was removed and a pit of 30 cm × 30 cm × 30 cm was dugout and soil samples were collected. Soil Organic Carbon was estimated by standard Walkley and Black (1934). Soil Organic Carbon Density (SOCD) was calculated as follows (Ramachandaran et al. 2007).

$$\text{SOCD (Mg ha}^{-1}) = \frac{\text{SOC (\%)} \times \text{CBD (Mg m}^{-3}) \times \text{layer depth(m)} \times 10^4 (\text{m}^2\text{ha}^{-1})}{100}$$

where,
SOCD = Soil Organic Carbon Density
CBD = Corrected Bulk Density

$$\text{CBD (Mg m}^{-3}) = \frac{\text{DBD (Mg m}^{-3}) \times (100 - \text{per cent coarse fraction})}{100}$$

where,
CBD = Corrected Bulk Density (Mg m^{-3})
DBD = Determined Bulk Density (Mg m^{-3})
Total SOC stock = SOC density (Mg ha^{-1}) × forest area (ha).

d) Carbon Dioxide Equivalent (CO_2e)

Sink or sequestration capacity is one of the ecosystem services, provided to us by the natural ecosystems. The carbon dioxide equivalent was calculated as per the following equation:

$$CO_2e \text{ (Mg)} = \text{Carbon Stock (Mg ha}^{-1}) \times 3.66$$

III. Results

a) Biomass Carbon Allocation

The total biomass in Barkot Range was 202.76 Megagram per hectare ($Mgha^{-1}$) for dry deciduous forest, 329.89 $Mgha^{-1}$ for moist deciduous forest and 293.67 $Mgha^{-1}$ in pure Sal forest. In Lachchiwala Range, total biomass was recorded in the range of 191.40 $Mgha^{-1}$ – 427.16 Mg ha^{-1}. Dry deciduous forest of Lachchiwala Range has the biomass contribution of 191.40 $Mgha^{-1}$ while the moist deciduous forest in Lachchiwala Range was recorded with 427.16 $Mgha^{-1}$. Pure Sal Forest in Lachchiwala Range has the contribution of 266.04 $Mgha^{-1}$.In Thano Range, the total biomass was 282.65 $Mgha^{-1}$, 411.83 $Mgha^{-1}$, 235.76 $Mgha^{-1}$, 170.42 $Mgha^{-1}$, 176.14 $Mgha^{-1}$ and 26.78 $Mgha^{-1}$ for dry deciduous, moist deciduous, pure Sal, pure Pine, degraded forest and scrub respectively.

The carbon stock density in Barkot Range varies from 101.38 $Mgha^{-1}$ to 164.95 $Mgha^{-1}$. Dry deciduous forest has the contribution of 24.54% while the moist deciduous forest contributed 39.92%. pure Sal forest in Barkot Range shared the contribution of 35.54%. In Lachchiwala Range, the carbon stock density was recorded 95.70 $Mgha^{-1}$ for dry deciduous forests, 213.58 $Mgha^{-1}$ for moist deciduous forests and 133.02 $Mgha^{-1}$ for pure Sal forest. The Thano Range recorded carbon stock density in dry deciduous forest (141.33 $Mgha^{-1}$), moist deciduous forest (205.92 $Mgha^{-1}$), pure Sal forest (117.88 $Mgha^{-1}$), pure Pine (85.21 $Mgha^{-1}$), degraded forest (88.07 $Mgha^{-1}$) and Scrub (13.33 $Mgha^{-1}$).

The total carbon stock in the three ranges was 3446882.72 Mg. The Barkot Range with a forest area of 6109 hectares (ha) has a carbon stock of 918899.76 Mg viz. 97527.56 Mg in dry deciduous forest, 597595.70 Mg in moist deciduous forest while pure Sal forest has 223776.5 Mg Carbon. Moist deciduous forest of Barkot Range has the contribution of 65.03% carbon. Similarly, the Lachchiwala Range recorded 1377647.6 Mg carbon stock in 7711 ha. Dry deciduous forest of Lachchiwala Range contributed 5.86% while the moist deciduous forest contributed 73.79% carbon. Pure Sal forest in Lachchiwala Range has the contribution of 20.33 % carbon. The Thano Range in its 6 forest types covering an area of 11,084 ha pooled 1150335.36Mg carbon. Maximum 47910.08 Mg (45.10%) contribution in Thano Range was by pure Sal forest (Table 1).

b) Soil Organic Carbon

Table 2 reveals the Soil Organic Carbon (SOC) in the different forest types of Study Sites. Barkot Range has the Soil Organic Carbon Density of 209.66 $Mgha^{-1}$ in Dry Deciduous Forest, 259.97 $Mgha^{-1}$ in Moist Deciduous Forest and 172.74 $Mgha^{-1}$ in Pure Sal Forest. Lachchiwala Range was recorded with 177.37 $Mgha^{-1}$ in Dry Deciduous Forest, 228.52 $Mgha^{-1}$ in Moist Deciduous Forest and 186.63Mg ha^{-1} in Pure Sal Forest. Thano Range has 219.43 $Mgha^{-1}$ in Dry Deciduous Forest, 250.07 $Mgha^{-1}$ in Moist Deciduous Forest and 180.90 $Mgha^{-1}$ in Pure Sal Forest. Degraded Forest in Thano Range was recorded with 167.01 $Mgha^{-1}$ of Soil Organic Carbon. Scrub was having 173.06 $Mgha^{-1}$ of Soil Organic Carbon Density. Pure Pine Forest was recorded with 161.66 $Mgha^{-1}$. The maximum (259.97 $Mgha^{-1}$) Soil Organic Carbon was recorded in Moist Deciduous Forest of Barkot Range while the minimum 161.66 $Mgha^{-1}$ was recorded from the Pure Pine Forest of Thano Range.

c) Net Carbon Stock

The total biomass carbon of three Ranges of Dehra Dun Forest Division was 3446882.72 Mg and total Soil Organic Carbon was 5058740.50Mg. The ratio between SOC and biomass carbon was 1.47. The carbon content in the soil was higher than the above-ground biomass carbon due to heavy exploitation from the forest. Higher content of Soil Organic Carbon than the aboveground biomass carbon indicates that the sequestered Soil Organic Carbon was the result of its original vegetation in the past before exploitation (Table 3).

d) Carbon Dioxide Mitigation by different forest types

The carbon dioxide mitigation (CO_2 equivalent CO_2e) of different study sites has been presented in Table 3. In Barkot Range, Dry Deciduous forest has the CO_2e of 1138.39 $Mgha^{-1}$ while the moist deciduous forest mitigated 1555.19 $Mgha^{-1}$ CO_2e. Pure Sal Forest of the Barkot Range has the contribution of 1169.64Mg ha^{-1} CO_2e. Dry Deciduous Forest of Lachchiwala Range mitigated 999.42 $Mgha^{-1}$ of CO_2e while the Moist Deciduous Forest mitigated the maximum (1618.08 $Mgha^{-1}$) of CO_2e. Pure Sal Forest of Lachchiwala Range mitigated 1169.91 $Mgha^{-1}$ of CO_2e. In the Thano Range, Moist Deciduous Forest has the maximum mitigation 1668.938 $Mgha^{-1}$ of CO_2e. Dry Deciduous Forest has the contribution of 1320.36 $Mgha^{-1}$ of CO_2e. Pure Sal Forest in Thano Range contributed 1093.54 $Mgha^{-1}$ of CO_2e mitigation of Carbon Dioxide. 903.55 $Mgha^{-1}$ of CO_2e, 933.59 $Mgha^{-1}$ of CO_2e and 684.61 $Mgha^{-1}$ of CO_2e was mitigated by Pure Pine Forest, Degraded Forest and Scrub respectively. Thano Range has the carbon dioxide mitigation share of 37.29% while the Lachchiwala Range shared 35.37%. The Barkot Range contributed 27.34% of the Carbon dioxide mitigation.

IV. Discussion

The role of forests in harvesting atmospheric carbon has gained considerable importance & debate in recent year. Biomass is an important parameter to assess the atmospheric carbon that is harvested by trees. In recent times, biomass-related studies have become significant due to growing awareness of carbon credit systems the world over.

Sharma et al. (2010) has reported 159.40 Mgha^{-1} in Moist Bhabhar *Shorea robusta* Forest while in present study, 164.95 Mgha^{-1}, 213.58 Mgha^{-1}, 205.92 Mgha^{-1} of Carbon density was recorded in Moist Deciduous Forest of Barkot Range, Lachchiwala Range and Thano Range respectively. Carbon density (74.50 Mgha^{-1}) was reported from dry-sub deciduous forest study conducted by Sharma et al. (2010) while in present study, 101.38 Mgha^{-1}, 95.70 Mgha^{-1} and 141.33 Mgha^{-1} Carbon density was recorded in Dry-Deciduous Forest of Barkot Range, Lachchiwala Range and Thano Range respectively. *Pinus roxburghii* has the carbon density of 73.30 Mgha^{-1} (Sharma et al. 2000) while in present study *Pinus roxburghii* forest has the carbon density of 85.21 Mgha^{-1}.

Haripriya (2000) reported that above ground biomass had 48.30 Mgha^{-1}C to 97.30 Mgha^{-1}C (approximately 50% of the biomass) in tropical deciduous forests of India. The carbon storage in the present study is much similar to in range as compared to the estimates made in different tropical forests (Atjay et al. 1979; Brown et al. 1994). Based on the growing stock and total area of sal forests in India, Lal and Singh (2003) reported 430.51 Mgha^{-1} average aboveground biomass of tree layer. Similar trends of estimation of Sal forests were also reported by some studies (Negi and Chauhan 2002; Dadhwal et al. 2006). In the Present study, Pure Sal Forest has the Carbon Density of 146.84 Mgha^{-1}, 133.02 Mgha^{-1}, 117.88 Mgha^{-1} in Barkot Range, Lachchiwala Range and Thano Range respectively. The study site is a natural Sal forest and lopping of trees for fuel and fodder, along with extraction of medicinal (*Zingiber roseum*) and ethanobotanical (*Pterospermum acerifolium*, *Calamus tenuis* etc.) plants are the major disturbances causing the forest degradation and affecting the carbon storage capacity of the forest. In addition to this, in the recent years, over mature Sal, and those infested by *Hoplocerambyx spinicornis* (Sal borers) were also removed by the forest department (Chauhan 2001). Various anthropogenic disturbances prevailing in the study site *viz*. collection of fodder and fuel wood, grazing of cattle, tremendous increase in the population of the Doon Valley has resulted in the forest degradation. The urbanization around the surroundings of the forest has the great impacts on the forest structure. All these disturbances have resulted in large canopy gaps leading to forest degradation.

The results of Soil Organic Carbon density in the present study were also found comparable with earlier studies carried out in Sal forests of Doon Valley. Negi and Chauhan (2002) reported Soil Organic Carbon in Sal forests, varies from 31.0 – 62.90 Mg ha^{-1} in the top 30 cm depth depending upon the tree density and age of the stand tree. They reported highest SOC density (62.9 Mgha^{-1}) in 30cm top soil of the Sal forests on flat area in Doon Valley. The highest density of SOC in our study was from Moist Deciduous Forest of Barkot Range, probably due to high density of trees and comparatively less anthropogenic pressure.

The capacity of forest to sequester carbon is a function of the productivity of the site and the potential size of the various pools - soil, litter, down woody material, standing dead wood, live stems, branches, and foliage. Forests play a critical role in regulating the Earth's climate through the carbon cycle; removing carbon from the atmosphere as they grow, and storing carbon in leaves, woody tissue, roots and organic matter in soil. Forests and other terrestrial systems annually absorb approximately 2.6 gigatons of carbon (GtC), or 9.53 gigatons of carbon dioxide equivalent ($GtCO_2e$), while deforestation and degradation of forests emit approximately 1.6GtC (5.87 $GtCO_2e$), for net absorption of 1GtC (3.67 $GtCO_2e$) (IPCC 2007a). Forests therefore play an important role in the global carbon cycle as both a "sink" (absorbing carbon dioxide) and a "source" (emitting carbon dioxide). Total of 31130702 $MgCO_2e$ of Carbon Dioxide was removed by three forest ranges of Doon Valley. Thano Range has the contribution of 11608107 $MgCO_2e$ while the Lachchiwala Range has sequestered 11010428 $MgCO_2e$ of Carbon Dioxide. Barkot Range has sequestered maximum 8512168 $MgCO_2e$ of Carbon Dioxide.

V. Conclusion

The role of forests in preventing and reducing Green House Gases (GHGs) is gaining recognition in market-based policy instruments for climate change mitigation. Climate Change Mitigation is a human intervention to reduce the sources or enhance the sinks of greenhouse gases and forestry sector can play a good role in mitigating the climate change. Forestry is one category of projects that can create carbon dioxide emission reduction credits for trading to offset emissions. Policies governing forest conservation and management are more effective when involving both mitigation and adaptation. Reducing emissions form deforestation and forest degradation (REDD) plus is an approach which can help in the climate change mitigation through (a) conservation of forest carbon stocks, (b) Sustainable management of forest and (c) Enhancement of forest carbon stocks. Properly designed and implemented, forestry mitigation options will have substantial co-benefits in terms of employment and income generation opportunities, biodiversity and watershed conservation, as well as aesthetic and recreational services. Forests of Doon Valley have the potential to mitigate the climate change through proper and effective implementation of mitigation programmes.

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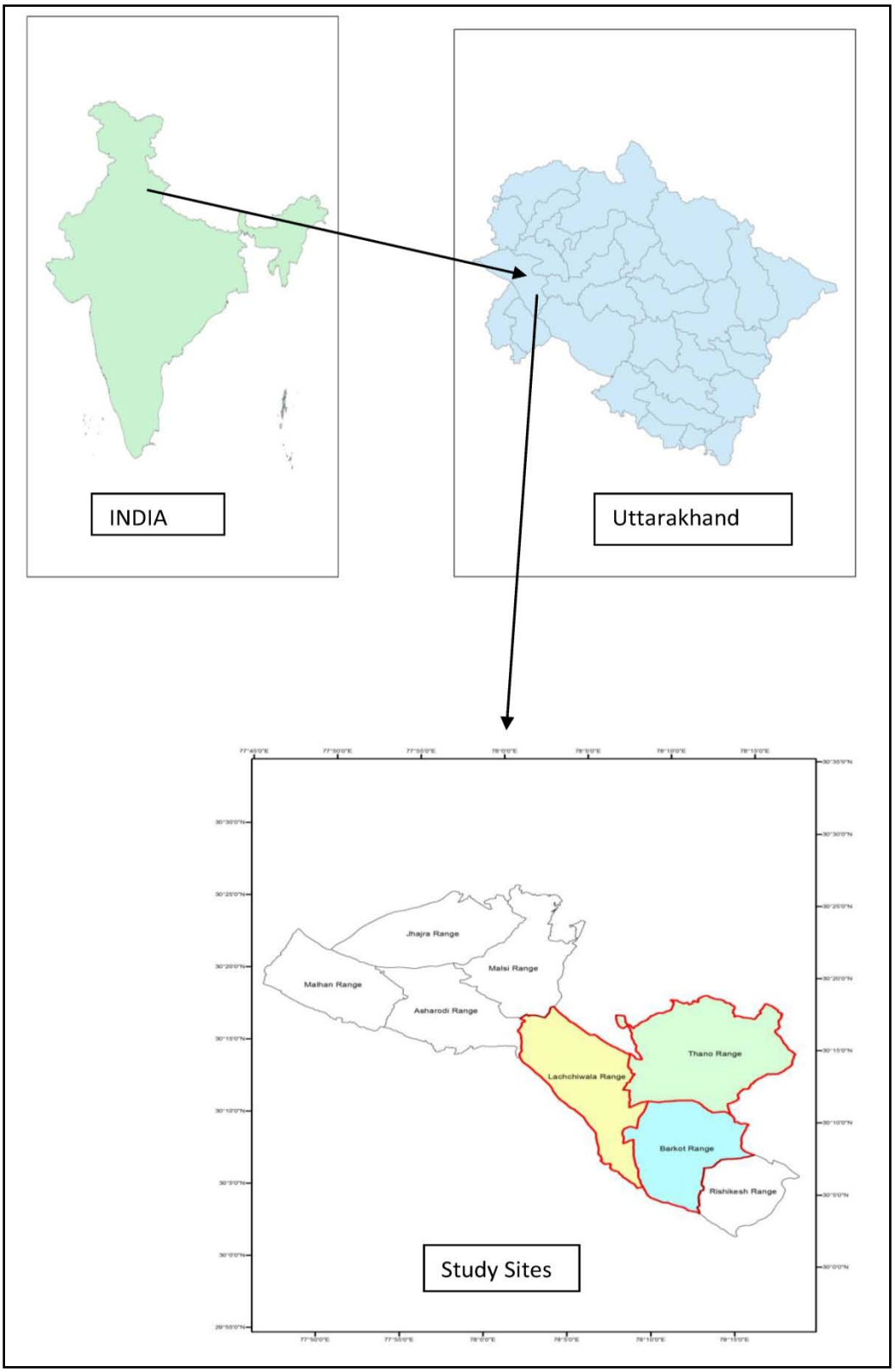

Figure 1 : Location of the study sites

Table1 : Biomass and Carbon Stock in the forests of Doon Valley

Study Site	Forest Type	Area (ha)	Total Biomass Density ($Mgha^{-1}$)	Carbon Density ($Mgha^{-1}$)	Carbon Stock (Mg)
Barkot Range	Dry Deciduous Forest	962	202.76	101.38	97527.56
	Moist Deciduous Forest	3623	329.89	164.95	597595.7
	Pure Sal Forest	1524	293.67	146.84	223776.50
Lachchiwala Range	Dry Deciduous Forest	845	191.40	95.70	80866.50
	Moist Deciduous Forest	4760	427.16	213.58	1016641.00
	Pure Sal Forest	2106	266.04	133.02	280140.10
Thano Range	Dry Deciduous Forest	325	282.65	141.33	45930.63
	Moist Deciduous Forest	1198	411.83	205.92	246686.20
	Pure Sal Forest	4402	235.76	117.88	518907.80
	Pure Pine Forest	3190	170.42	85.21	271819.90
	Degraded Forest	544	176.14	88.07	47910.08
	Scrub	1425	26.78	13.39	19080.75

Table 2 : Soil Organic Carbon Stock in the forests of Doon Valley

Study Site	Forest Type	Soil Organic Carbon Density ($Mgha^{-1}$)	Carbon Stock (Mg)
Barkot Range	Dry Deciduous Forest	209.66	201691.00
	Moist Deciduous Forest	259.97	941862.25
	Pure Sal Forest	172.74	263250.12
Lachchiwala Range	Dry Deciduous Forest	177.37	149875.37
	Moist Deciduous Forest	228.52	1087749.49
	Pure Sal Forest	186.63	393041.31
Thano Range	Dry Deciduous Forest	219.43	71313.19
	Moist Deciduous Forest	250.07	299588.65
	Pure Sal Forest	180.90	796338.09
	Pure Pine Forest	161.66	515708.16
	Degraded Forest	167.01	90853.82
	Scrub	173.66	247469.06

Table 3 : Net Carbon Stock and Carbon dioxide mitigation by the forests of Doon Valley

Study Site	Forest Type	Net Carbon Stock (Mg)	CO2e ($Mgha^{-1}$)	Total CO_2e (Mg)
Barkot Range	Dry Deciduous Forest	299218.56	1138.39	1095139.9
	Moist Deciduous Forest	1539476.10	1555.19	5634482.5
	Pure Sal Forest	487034.28	1169.64	1782545.5
Lachchiwala Range	Dry Deciduous Forest	230741.87	999.42	844515.24
	Moist Deciduous Forest	2104390.29	1618.08	7702068.5
	Pure Sal Forest	673181.43	1169.91	2463844
Thano Range	Dry Deciduous Forest	117245.44	1320.36	429118.31
	Moist Deciduous Forest	546280.81	1668.94	1999387.8
	Pure Sal Forest	1315245.85	1093.54	4813799.8
	Pure Pine Forest	787528.06	903.55	2882352.7
	Degraded Forest	138763.90	933.59	507875.88
	Scrub	266549.81	684.61	975572.31

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Manganese Ore Minerals Assemblages and Mineral Paragenesis with the Help of Ore Petrography and XRD Studies of Balaghat District, (M.P.) India

By F. N. Siddiquie, Kh. Burhamuddin, Mohd. Shaif & Juned Alam
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Abstract- The regionally metamorphosed syngenetic sedimentary bodies of manganese ores in the Sausar Group of Balaghat district, Madhya Pradesh exhibit a definite trend in the formation and transformation of manganese oxide phases with progressive metamorphism. A regional trend is clearly noticeable from the paragenesis of Ore minerals in the manganese ore bodies from different metamorphic zones. Braunite forms at a very low temperature, appearing in the chlorite zone of regional metamorphism, and it continues in stable form right up to the sillimanite zone. Bixbyite as a high temperature mineral appears first in biotite zone and also appears in the sillimanite and almandine zone in the Balaghat. It shows evidences, at places, of conversion to hausmannite, and a second generation of this mineral is also found to have been formed as conversion product in the cleavages of the latter in ore bodies of sillimanite zone in Tirodi areas. Free hausmannite is characteristic of only the sillimanite zone. Bixbyite is accompanied by hollandite which is also a transformation product of psilomelane formed in elevated temperature condition. The association of braunite, bixbyite and hollandite (in the absence of jacobsite, hausmannite and vredenburgite) continues to the almandine zone (Bharweli-Ukwa area).

Keywords: manganese ore, sausar group, balaghat district, metamorphism, paragenesis, metamorphic zones, manganese oxide minerals.

GJSFR-H Classification : FOR Code: 040307

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F. N. Siddiquie [α], Kh. Burhamuddin [σ], Mohd. Shaif [ρ] & Juned Alam [ω]

Abstract- The regionally metamorphosed syngenetic sedimentary bodies of manganese ores in the Sausar Group of Balaghat district, Madhya Pradesh exhibit a definite trend in the formation and transformation of manganese oxide phases with progressive metamorphism. A regional trend is clearly noticeable from the paragenesis of Ore minerals in the manganese ore bodies from different metamorphic zones. Braunite forms at a very low temperature, appearing in the chlorite zone of regional metamorphism, and it continues in stable form right up to the sillimanite zone. Bixbyite as a high temperature mineral appears first in biotite zone and also appears in the sillimanite and almandine zone in the Balaghat. It shows evidences, at places, of conversion to hausmannite, and a second generation of this mineral is also found to have been formed as conversion product in the cleavages of the latter in ore bodies of sillimanite zone in Tirodi areas. Free hausmannite is characteristic of only the sillimanite zone. Bixbyite is accompanied by hollandite which is also a transformation product of psilomelane formed in elevated temperature condition. The association of braunite, bixbyite and hollandite (in the absence of jacobsite, hausmannite and vredenburgite) continues to the almandine zone (Bharweli-Ukwa area).

The trend of formation and transformation of manganese oxide minerals with increasing of temperature in metamorphic condition has been indicated. The absolute temperature of formation of the individual phases and the mineralogical trend found in the manganese ore bodies could be correlated to the results from phase equilibrium studies including manganese, iron and silica.

Keywords: manganese ore, sausar group, balaghat district, metamorphism, paragenesis, metamorphic zones, manganese oxide minerals.

I. Introduction

Balaghat district is placed at the Madhya Pradesh-Maharashtra manganese belt of central India extending from 21°19' to 22°24' North latitude and 79°31' to 81°3' East longitude. These manganese belts make an arcuate belt of about 150 kms long and 25 to 30 meters wide in NE-SW direction and extend in the East-West direction from Chhindwara district in the West through Nagpur and Northern Bhandara District in the middle of the Balaghat (Fermor, 1909, 1936; and Narayanaswami, et. al. 1963). The manganese deposit of the Balaghat district, M.P., founds as NNE-SSW to ENE-WSW trending conformable bands in the form of lenses of varying sizes, enclosed within the meta-sedimentary sequence of Sausar Group of rocks of Precambrian age shown in Fig. 1 (Banerjee, et. al. 2007). The Madhya Pradesh-Maharashtra manganese belt is the largest manganese ore deposits of India which are intensely deformed and metamorphosed varies from green schist facies to upper amphibolite facies with gradual increase in the grade of metamorphism from East to West (Gupta, et. al. 2009).

Three manganese mines viz. Bharweli mine, Tirodi mine and Ukwa mine are selected for mineragraphic studies in Balaghat district. These are working manganese mines operated under the Manganese ore India limited (MOIL) in which Bharweli mine (largest underground manganese mine in the Asia), Tirodi mine (open cast mine) and Ukwa mine (both open cast and underground mine). Braunite, bixbyite, hollandite, jacobsite, pyrolusite, psilomelane, vredenburgite and hausmannite are observed as predominance manganese mineral of these mines. The study area was studied in detailed by (Fermor, 1909) in his classic memoirs and Dunn & Roy (1939); Roy, (1958, 1962, 1964(a), & 1964(b), 1966; Babu and Nayak (1961); Narayanaswami, et. al. (1963); Shukla and Anandalwar (1973);Vemban and Nagarajaiah (1974); Jain, et. al. 1990; Dasgupta, et. al. (1993); Banerjee, et. al. (2007); Gupta, et. al. 2009;Kanungo, et. al. (2003, 2007, 2008, & 2014) and Kanungo and Sutaone (2013) were carried out detailed mineralogy of the study area and proposed their views. Systematic mineragraphic study of manganese ore of my study area was not carried out by earlier workers. Banerjee, et. al. (2007), Roy, (1964, a & b) and Roy, et. al. 1986, carried out the mineralogy, paragenesis and genesis of manganese ore and associated host rocks of the study area. Roy, 1964(a & b) point out that the paragenesis of manganese minerals is associated with the gondites rock of Tirodi.

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The authors are trying to establish the paragenetic trend of the manganese ores from different metamorphic zones and have tried to correlate the mineral assemblages and mineral paragenesis of manganese ores of Bharweli, Tirodi and Ukwa area of Balaghat district, Madhya Pradesh of Sausar group with the help of these works. The mineralogical characteristics between the manganese ores of different location from the study area reveal some variation in mineral assemblages of the primary and secondary manganese ores.

II. Geology of the Balaghat Manganese Ores

The manganese ore bodies of the study areas occur conformably with the metasedimentary sequence of the Sausar Group (Fermor, 1909; Pascoe, 1950; Straczek et al., 1956; Narayanaswami, et al., 1963; Vemban and Nagarajaiah, 1974). The Sausar Group hosts the largest productive manganese ore deposits of India, contributing about 80% of the total production of the country. Rocks of Sausar Group consists of a sequence of regionally metamorphosed cross bedded quartzite, pelite, carbonate and manganese ores deposited on a stable platform (Bandyopadhyay et. al. 1995). The meta-sedimentary manganese ore deposits of large size are hosted by the gneiss and quartzites in the Balaghat district of M.P. The important mines with better exposure of the ore bodies and host rocks include Bharweli, Tirodi and Ukwa mines. The manganese deposits are importantly available within the pelitic Mansar Formation as pointed out by Roy, 1966. Older and younger gneisses, migmatites, ortho-gneisses, late and post-tectonic granite plutons, pegmatites and vein quartz, all of apparent Precambrian age have been partly mixed up with and emplaced in the Sausar rocks (Narayanaswami, et. al. 1963). Rocks of Sausar group are intruded by amphibolites appear to have a calcareous parentage (Subramanyam, 1972). Detailed geochronologic studies are lacking within this belt; however, Roy et al. (2006) on the basis of Rb-Sr and Sm–Nd geochronological studies, argue that the main phase of metamorphism (amphibolite-grade) took place between 800 and 900 Ma.

Folding is the major structural control and foliation planes are a minor structural control for the concentration of manganese due to tectonism and metamorphism. The drag folding, foliation planes, kink bands, pressure shadow zones, strain slip cleavages and the joints as reported by Siddiquie (2004) are zones along which supergene enrichment of the manganese ores have been carried out by meteoric waters. Jain, et. al. (1990) proposed that the rocks of Bharweli-Ukwa manganese belt of Balaghat may be admitted an independent stratigraphic status of 'Bharweli Group'. younger to the Sausar Group. The stratigraphic succession proposed by Narayanaswami, et. al., (1963) is given in the Table.1.

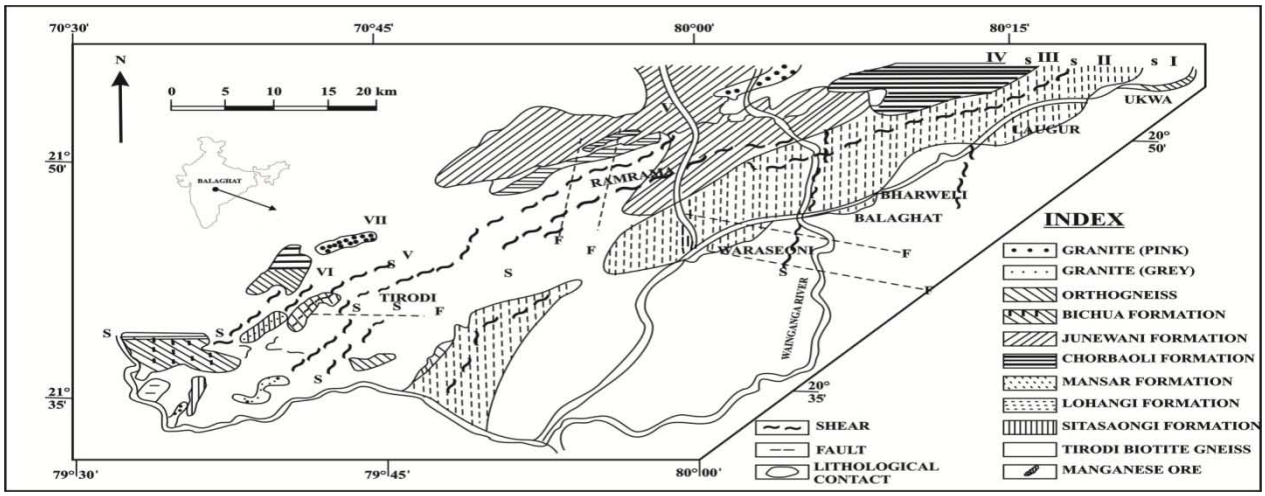


Figure 1 : Generalized geological map of Balaghat district, Madhya Pradesh (Banerjee. et. al. 2007)

III. Field Work and Sampling

About forty seven Manganese ore samples and fifteen host rocks were collected systematically from the study area. Out of this, 30 Mn Ore samples were selected for mineragraphic and geochemical studies. The manganese ores of the Balaghat mines were studied in the field with reference to the tectonic and structural controls of ore deposition. The present sampling and field data with photographic documentation was carried out in standard order. Preferential and careful selection of both primary and secondary ores was carried out for the present piece of research work. The selected samples were coded and packed as per their respective locations for laboratory use. The primary ore samples like braunite ores show typical metamorphic banding as seen in fig. 2. (a-d). The secondary ore samples especially pyrolusite and psilomelane (Fig. 3).

IV. Materials and Methods

Out of 47 Mn Ore samples collected from the study areas, 30 Mn Ore samples were selected for mineragraphic studies. These mineragraphic microscopic studies of Mn Ore samples were conducted by polished blocks; examined the minerals of this polished blocks under the reflected light of microscope with the help of air and oil immersions lenses. 13 manganese ore samples were selected for XRD analysis to confirm the ore minerals present in the manganese ore samples. XRD analysis was conducted by XPERT-PRO PHILIPS at Geological Sciences Department, Jadavpur University, Kolkata. Analytical XRD techniques were used on operating current 40KV-30ma and results were obtained on 2θpositions in the form of peaks of count time of 30 minutes.

Table 1 : Stratigraphic succession of Sausar Group (Bandopadhyay, et. al., 1995, modified from Narayanaswami, et. al., 1963)

FORMATION	LITHOLOGY
Bichua Formation	Dolomite, Marble, Calc silicate gneiss schist.
Junewani Formation	Metapelite (Mica Schist), Quartzite, granulite, biotite-Gneiss (Reworked basement).
Charboli Formation	Quartzite, feldspathic Schists, Gneisses, Autoclastic Quartz, Conglomerate.
Mansar Formation	Metapelite (mica-schists and gneisses), graphitic Schists, Phyllite quartzite, major manganese deposits and gondite.
Lohangi Formation	Calc-Silicate Schists and gneisses, marble, Manganese deposits.
Sitasaongi Formation	Quartz mica Schists, Feldspathic Schists, mica gneiss, Quartzite, Conglomerate.
Tirodi Gneiss	Biotite gneiss, Amphibolite, Calc-Silicate Gneiss (Tirodi Gneiss), Granulites, Mica Feldspathic Schists.
Unconformity	
Older Metamorphics	Charnockite, Orthogneisses and Granite Biotite Gneisses, hornblende Gneisses, Amphibolites and calcgranulites

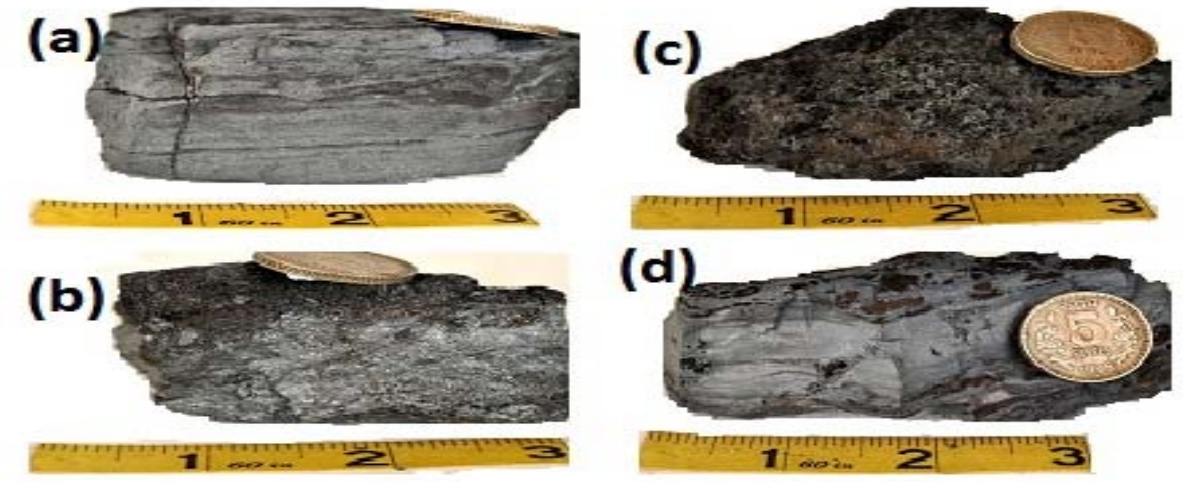


Figure 2 : Hard, soft massive and banded manganese ore sample collected from a) Bharweli underground mine b) Tirodi open cast mine, c) Tirodi underground mine and d) Ukwa underground mine, Balaghat district, M.P.

V. Paragenetic Trends and Regional Metamorphism of Manganese Ores

Mineralogical, textural and paragenetic studies of the manganese ore bodies from different metamorphic zones of the Sausar Group (Madhya Pradesh-Maharashtra) have been carried out by the author and his associates (Roy, 1958, 1959, 1961, 1962, 1963; Roy and Mitra, 1962; Roy and Nandy, 1962; Roy and Purkait, 1965; etc.). The metamorphic zones of the Sausar Group have been delineated by the study of the pelitic rocks (phyllites and mica schists) with chlorite, biotite, almandine, staurolite, kyanite and sillimanite. Since the manganese ore bodies are intimately interbanded and co-folded with these rocks, they have been assumed to have undergone the same intensity of metamorphism. The mineralogical constituents and their paragenesis in these individual ore deposits of study areas have been given in Table 2.

Table 2: Paragenesis of the ore minerals in deposits of Balaghat Manganese Belts (M.P.)

	METAMORPHIC	COLLOIDAL	SECONDARY
Almandine zone	Bharweli area, (Roy, 1962)		
	I II Braunite Bixbyite Hollandite Manganite Hematite Pyrolusite Cryptomelane		
Sillimanite zone	Tirodi area, (Roy, 1958 & 1962)		
	Braunite Bixbyite Vredenburgite (Metastable) Hausmannite Jacobsite Hollandite Manganite Pyrolusite Cryptomelane Hematite		
Almandine Zone	Ukwa area, (Roy, 1962)		
	I II Braunite Bixbyite Hollandite Manganite Hematite Pyrolusite Cryptomelane		

It may be seen that in all ore bodies of low temperature formation (mainly of colloidal derivation), pyrolusite, cryptomelane, etc., are commonly present, which reflects the stability of the minerals closely approximating MnO_2 in composition, with mainly Mn^{4+} in the low temperature condition. Therefore, in the original syngenetic manganiferous sediments as well, in an oxidising condition, there is a strong possibility of the presence of these minerals in stable assemblage.

When the sedimentary manganese formations are regionally metamorphosed, braunite is the earliest mineral to crystallize in most metamorphic deposits. In most cases, this early braunite is considerably deformed, showing that the deformational forces continued to act beyond its crystallisation period. Bixbyite generally follows this braunite though in some cases the relation is unclear in Tirodi area. According to Schneiderhohn (l931), bixbyite was formed by reaction between braunite and hematite as represented in the following equation:

$$Mn.\ MnO_3 + Fe_2O_3 \rightarrow (Mn.Fe)\ MnO_3$$

Braunite Hematite Bixbyite

A second generation braunite has formed replacing bixbyite along crystallographic directions and grain boundaries and such replacement is understandable considering the similarity in structure of the two minerals. Braunite, however, never yields bixbyite by replacement, primarily due to the fact that the silica, in its structure, is very well screened and it imparts a great stability to the Mn^{3+} in the structure of the mineral. In increasing temperature condition, generally the formation of bixbyite takes place later than early braunite, indicating its higher temperature of formation and everywhere it is apparent that bixbyite crystallised independent of braunite. Here the bixbyite follows the first generation braunite in the sequence of crystallisation, though is itself converted to a second generation undeformed braunite later in the waning stage. The same assemblage of manganese oxide phases continues with increasing intensity of metamorphism even after the appearance of almandine in the pelitic schists (as at Bharweli-Ukwa area (almandine zone). In almandine zone, at Bharweli-Ukwa area, bixbyite formed at the peak of metamorphism with its crystallisation outlasting deformation. In spite of

considerable iron in the bulk composition, jacobsite or vredenburgite did not form. It may be noted, however, that in Bharweli-Ukwa area, the metamorphism had, apparently, just reached almandine zone as shown by the very minute size ' of the garnets and the relative fine grained nature of the phyllitic schists. Jacobsite and vredenburgite, however, definitely appear in stable assemblage in sillimanite zone in the Tirodi area. In the sillimanite zone, bixbyite continues to be stable with jacobsite, vredenburgite and free hausmannite at the peak of metamorphism. Thus the assemblages of the manganese oxide minerals can be plotted against different metamorphic zones of study areas as shown in Table 3.

Table 3 : Specific assemblages of manganese oxide minerals in different metamorphic zones (Roy, 1964b)

	Area	Manganese oxide mineral assemblages.
Low temperature 'gel' formation	Dongri Buzurg	Pyrolusite-cryptomelane-manganite-coronadite
Chlorite zone	Shivrajpur, Gujarat	Braunite- (pyrolusite-cryptomelane)
Biotite zone	Kajlidongri, Jhabua District, M.P.	Braunite-bixbyite-hollandite-(pyrolusite-cryptomelane-hematite)
Almandine zone	Bharweli-Ukwa area, Balaghat District, M.P.	Braunite-bixbyite-hollandite-manganite-(pyrolusite-cryptomelane)
	Dongri Buzurg (west)-Kurmura area, BhandaraDistrict, Maharashtra.	Braunite-hollandite-manganite-(pyrolusite-cryptomelane)
Staurolite-Kyanite zone	Chikla-Sitasaongi area, Bhandara District Maharashtra	Braunite-bixbyite-hollandite-manganite-(pyrolusite-cryptomelane) Braunite-vredenburgite-hollandite-(pyrolusite-cryptomelane) Braunite-bixbyite-jacobsite-hollandite-(pyrolusite-cryptomelane)
Sillimanite zone	Gowahari Wadhona area, Chhindwara District, Madhya Pradesh	Braunite-bixbyite-hollandite-manganite-(pyrolusite-cryptomelane) Braunite-bixbyite-vredenburgite-jacobsite-hausmannite-(pyrolusite-cryptomelane
	Ramdongri-Gumgaon area, Nagpur District, Maharashtra	Braunite-vredenburgite-bixbyite-hausmannite-(pyrolusite-cryptomelane) Braunite-bixbyite-jacobsite-hausmannite-manganite-(pyrolusite-cryptomelane) Braunite-vredenburgite-hollandite-hausmannite-(pyrolusite-cryptomelane)
	Tirodi-Sitapathore area, Balaghat District, Madhya Pradesh.	Braunite-bixbyite-hollandite-manganite-(pyrolusite-cryptomelane) Braunite-hausmannite-jacobsite-(pyrolusite-cryptomelane) Braunite-bixbyite-vredenburgite-(pyrolusite-cryptomelane)

VI. Ore Mineral Assemblages

The ores microscopic and XRD data supported by the geochemical data of the respective samples from the manganese mines of the study area have shown a well-developed ore mineral paragenesis and assemblages with respect to the environmental conditions. The mineral assemblages are neither uniform for all the operating mines and quarries nor they are uniform in different levels with depth. However there is some variation in mineral assemblages within the study area. Though the number of manganese minerals found in nature is considerably large, only a few are particularly important, in representing different pressure-temperature conditions during geological processes. This study will only be confined to the consideration of these minerals. They are pyrolusite (MnO_2, psilomelane [$(Ba, H_2O)_2Mn_3O_{10}$, Wadsley, 1952, 1953], cryptomelane (KMn_8O_{18}, Richmond and Fleischer, 1942), braunite ($3Mn_2O_4$, $MnSiO_3$), bixbyite $(Mn, Fe)_2O_5$, vredenburgite $(Mn,Fe)_3O_4$) jacobsite ($MnFe_2O_4$) and hausmannite ($MnsO_4$).Similar mineralogical details of the study area are also reported by many workers (Fermor, 1909; Roy, 1964 a & b; Banerjee, et. al. 2007 and Siddiquie, 2010) and were taken into due consideration for unveiling the possible mineral paragenesis.

a) *Primary ore minerals assemblages and mineral paragenesis*

The dominant Mn-minerals found in these ores include rhodochrosite, braunite, bixbyite, vredenburgite, hausmannite and jacobsite, spessartite and rhodonite. The important assemblages and paragenesis are detailed as follows:

Rhodochrosite-braunite-bixbyite-rhodonite
Jacobsite-hausmannite-vredenburgite
Hausmannite-rhodonite-pyroxmangite-spessartite

i *Rhodochrosite-braunite-bixbyite–rhodonite*

This assemblage is the characteristic of primary ores of Balaghat district. The diagenetic origin of rhodochrosite ($MnCo_3$) is evident in its morphology (Fig. 3 & 6) in many samples from hinge zone of folds. It is common in metamorphosed manganese ores of India, Bulgaria and Urals. Rhodochrosite is rarely reported as an intermediate oxidation product of Mn-carbonate in supergene oxidation. The bulk of this mineral is represented by minute spherulites of threadlike crystals that grew in a fine-grained carbonate or silicate matrix. The spherulites of rhodochrosite in Balaghat manganese ore deposits resemble rhodochrosites of Bulgaria and Southern Urals which are completely diagenetic as worked out by Aleksiev (1960). The ore samples contains rhodochrosite with quartz are specifically from the hinge zones of the folds, where they were least affected by the metamorphism. In many places, fine intergrowths of rhodochrosite with quartz are observed and these two react with each other to crystallize rhodonite as;

$$MnCo_3 + SiO_2 = Mn(SiO_3) + Co_2 \quad \text{(Reaction -1)}$$

(Rhodochrosite) (Quartz) (Rhodonite)

The replacement of carbonate with pyroxenoid is seen in the banded ore (Fig. 4). The rhodochrosite crystals themselves contain numerous inclusions of both rhodochrosite and quartz (Fig. 7).

Braunite (Mn_7SiO_{12}) is an important lower oxide of manganese and takes up manganese during the increasing grade of metamorphism from bixbyite. Braunite has about 10-Wt% of SiO_2 and is not a pure oxide. It is rather a silicate but conventionally called as lower oxide of Mn. It breaks down as per the following process;

$$Mn_7SiO_{12} = 3\,Mn_2O_3 + MnSiO_3 \quad \text{(Reaction-2)}$$

(Braunite) (Bixbyite) (Rhodonite)

In principle, the above pair can serve as an application in geochronology. Braunite commonly found in all metamorphosed deposits from the diagenetic to granulite facies (800^0-900^0c) with varied composition due to Mn^{3+}, Fe^{3+} exchange with bixbyite. Braunite is present in Archaean and Proterozoic manganese deposits of Kalahari, S. Africa and India containing around 4.5% of SiO_2Wt% and 4.5% of CaO (Roy, 1981). Depending upon the bulk composition (availability of Si, Fe etc.), temperature and oxygen fugacity, braunite and bixbyite may form together in metamorphosed manganese oxide ore body (Muan, 1959a). Pyrolusite in this assemblage is of secondary replacement origin and indicates the enrichment of manganese by supergene enrichment process in the zone of weathering (Fig.3). In metamorphosed manganese ore deposits of the Balaghat, the manganese silicate ore (silicate-oxide, silicate-carbonate and mixed assemblages) reflect the initial chemical and mineralogical composition of the sediments and their intensity of metamorphism. The crystal structure of the metamorphic braunite is not identical to that of the normal braunite. The c-axis of the metamorphic one is double to that of normal braunite and has been named as Braunite II as a distinction from normal Braunite (Braunite I). Braunite II is the only one of its kind in the world believed to be formed due to hydrothermal activity. Due to the fact of crystallographic differences the difference in optical behaviour and XRD patterns (Fig. 9-11) of the present braunite from sedimentary braunite is very obvious.

ii *Jacobsite-Hausmannite-Vredenburgite*

This assemblage is typical in the most continental meta-sedimentary and metamorphosed manganese ores. The assemblage is characteristic of the primary ores of deeper levels in some mines of the study area representing the metamorphosed manganese beds of the district. The hausmannite lamellae also show pleochroism and anisotropies in shades of dark to green (Fig. 5). Vredenburgite intergrown the hausmannite (Mn-rich member) and jacobsite (Fe rich member) in the primary ore samples are frequently observed in the studied ore (Fig. 5). The individual grains often show a well-developed lamellar twinning (Fig. 5). The present observations support the results of Deb (1939) and Roy, (1958) where there is no homogeneity in Vredenburgite.

The formation of hausmannite in metamorphosed manganese oxide ore is a function of high temperature and concomitant reduction and its presence, in the absence of jacobsite, reflects a bulk composition low in iron (Bhat, 2014) (Fig. 5). The formation of jacobsite depends on the iron content in the original bulk composition, temperature and oxygen fugacity. Braunite a lower oxide of manganese on heating gives rise to hausmannite was shown by laboratory experiments conducted by Orcel and

Pavlovitch (1931) supporting the paragenesis of the assemblage through metamorphism in the present research work.

iii *Hausmannite-rhodonite-pyroxmangite-spessartite*

Admixtures of Mn-carbonate, aluminous sediments and silica and manganiferous sheet silicates in volcanogenic sediments may also lead to the formation of spessartite in a rising temperature (Hsu 1968). The presence of rhodochrosite with or without quartz in some lenses of manganese ores of Balaghat district, (M.P.), represents the products of the original carbonate-silicate-oxide rock that escaped latter metamorphism. Rhodochrosite often replaces Mn-oxides completely. However, where the entire resource of carbon dioxide was consumed in the course of carbonation, an excess of manganese could have been retained in the oxide form as hausmannite.

The primary ores enriched in silica, Al, Mn and Fe are largely composed of quartz, pyroxmangite and rhodonite. Some samples are mostly composed of rhodonite or pyroxmangite and quartz with small to negligible amounts of rhodochrosite, calcite, peimontite and epidote are sporadic (Fig. 4). The relationships between these minerals are equivocal. In many places, fine intergrowths of rhodochrosite with quartz are observed; however, elsewhere, quartz and rhodochrosite do not make up a stable assemblage but react with each other to crystallize pyroxmangite or rhodonite as the above reaction-1.

The pyroxmangite and rhodonite crystals themselves contain numerous inclusions of both rhodochrosite and quartz. Pyroxmangite and rhodonite could have formed not only as products of reaction of quartz with rhodochrosite (Reaction-1) but also as a result of other processes, for example, by interaction of quartz with caryopilite (reaction 3) or Mn-oxides. At an excess of SiO_2, the quartz-pyroxmangite (rhodonite) assemblage was formed in ore in all cases. The Mn-rich hausmannite–tephroite, rhodochrosite-tephroite rocks and rocks close in composition due to silica gain. Schematically this process can be ascribed as the following reaction (for the particular case of rhodonite formation);

$$Mn_2(SiO_4) + (SiO_2)\,aq \rightarrow 2Mn(SiO_3) \qquad \text{(Reaction-3)}$$

Tephroite — Solution — Rhodonite

In accordance with Hsu (1968), the temperature of spessartite formation at a pressure of 2.5 kbar should be not lower than 410°C as possible pressure and temperature for metamorphism of Balaghat manganese ores. At the same time, spessartite is also observed as primary ore minerals at this deposit. Spessartite crystallization at high temperature was also suggested by researchers of manganese deposits in Belgium, Ghana, California and other regions (Flohr and Huebner, 1992; Theye, et. al., 1996; Nyame, 2001). The primary ores that occur throughout the banded stratiform ore horizons are largely of pyroxmangite(rhodonite), rhodochrosite and quartz; with spessartite (Fig. 4 & 7). With regard to mineral assemblages, quartz, hausmannite, rhodochrosite, pyroxmangite are possibly important minerals formed in the main ore layer in the course of burial metamorphism at a maximum temperature and pressure of 250° C and 2.5 Kb respectively. The formation of pyroxmangite and rhodonite depended on the Ca distribution in ore at constant temperature and pressure. It is possible that pyroxmangite was formed in ore depleted in Ca, whereas enrichment in Ca led to the appearance of rhodonite. The manganese content in jacobsite increases with the grade of metamorphism from low green schist to amphibolite facies. Oxidation of $FeSiO_3$ - rich and hence rhodonite or pyroxmangite may result in micrographic intergrowth of jacobsite and rhodonite. The textural relationship of rhodonite and spessartite reveals overlapping or cogenetic growth. Spessartite idioblasts are seen embedded in secondary pyrolusite and quartz matrix throughout in the primary ores (Figure 4 &7).

b) Secondary ore mineral assemblages and mineral paragenesis

i *Pyrolusite-cryptomelane-ramsdellite-maghemite*

Cryptomelane is mostly found in low temperature metamorphic and weathering environments. Cryptomelane containing samples are soft, black, velvety ground mass but in some samples consist of numerous, very thin, closely spaced needles of cryptomelane or hollandite oriented with their long axes perpendicular to the velvety surface. Cryptomelane, a low temperature mineral converts into bixbyite at 600^0 C. However the dominance of cryptomelane in some samples indicates least conversion. The presence of the higher oides of manganese in secondary ore sample is a function of high chemical activity in the system. For cryptomelane, the sum of Na + K + Ba + Sr +Ca of the geochemical data goes around (Hewett, 1963). The accommodations of large cations depend upon the temperature of the environment of formation and hence the origin of these minerals becomes distinct. The abundance of pyrolusite in the Balaghat manganese ore is in close association with cryptomelane in most of the samples (Fig. 5 & 8). Pyrolusite and cryptomelane are also seen in the cracks and boundaries of other minerals and appears to have developed at the expense of latter, presumably by the Mn ions changing positions (Bystrom and Bystrom, 1950). Ramsdellite mostly observed as tabular to blocky

crystals in this assemblage follows either hollandite or psilomelane in the paragenetic sequence. One possible explanation of this sequence is that in the absence of the large cations present in the hollandite structure the double strings composed of oxygen octahedra around manganese ions may be knitted together to form a ramsdellite-like arrangement (Bystrom and Bystrom, 1950). The appreciable strontium content and the sympathetic variation of strontium with barium in cryptomelane and psilomelane indicate that the strontium is probably present in the structure of these minerals and perhaps substitutes in barium or water molecule sites in cryptomelane.

The presence of strontium in these sites may be responsible for some of the differences between XRD powder patterns of cryptomelane as well as the optical properties. The assemblage suggests supergene alteration and enrichment of higher oxides from the high temperature earlier mineral of metamorphosed nature. The association of magnetite and magnesite suggest supergene alteration of the Mn-Fe component of the primary ores of the study area. Occurrence of globular, colloform, concentrically zoned and other structures typical of gel crystallization is characteristic of the studied ore from different blocks of the study area.

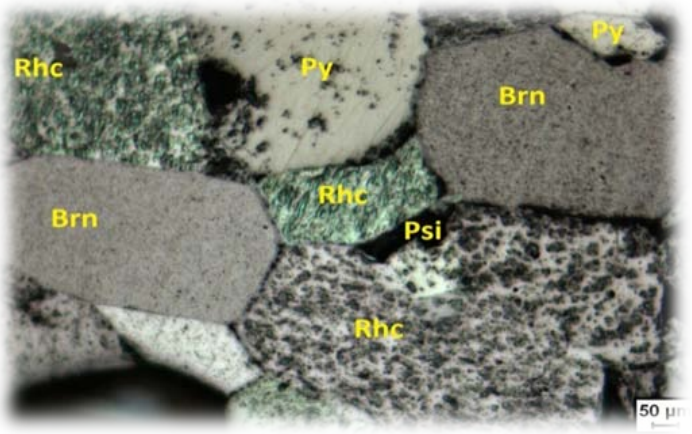


Figure 3 : Ore microphotograph showing lineated rhodochrosite (Rhc) with secondary pyrolusite (Py) and psilomelane (Psi) preserving the granoblastic texture and granulitic fabric in manganese ores from Bharweli mine, Balaghat district, M.P India

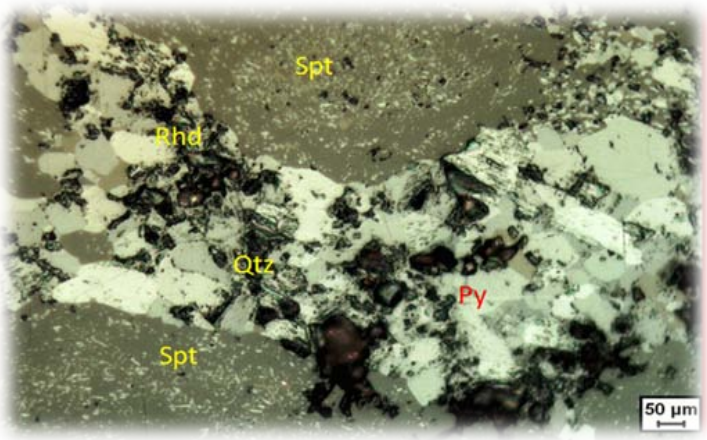


Figure 4 : Ore microphotograph showing rhodonite (Rhd), spessartite (Spt), and quartz (Qtz) as a metamorphic mineral assemblage in the metamorphosed ores from Ukwa Mine, Balaghat district, M.P India

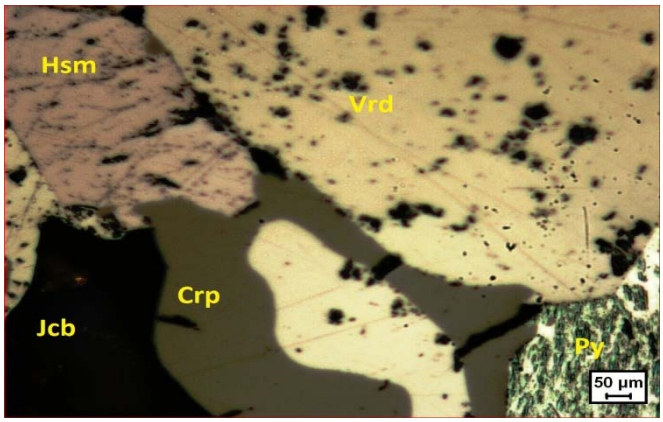
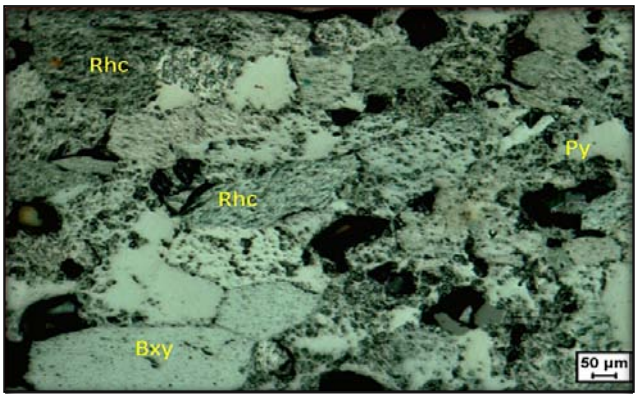


Figure 5 : Ore microphotograph showing sharp contacts between hausmannite (Hsm), jacobsite (Jcb), pyrolusite (Py) and cryptomelane (Crp) in the metamorphosed ores, Tirodi Mine, Balaghat district



Figue 6 : Ore microphotograph showing spherulites of rhodochrosite with bixbyite and secondary pyrolusite preserving the granoblastic texture and fabric as the metamorphic indicator from Bharweli mine, Balaghat district, M.P India

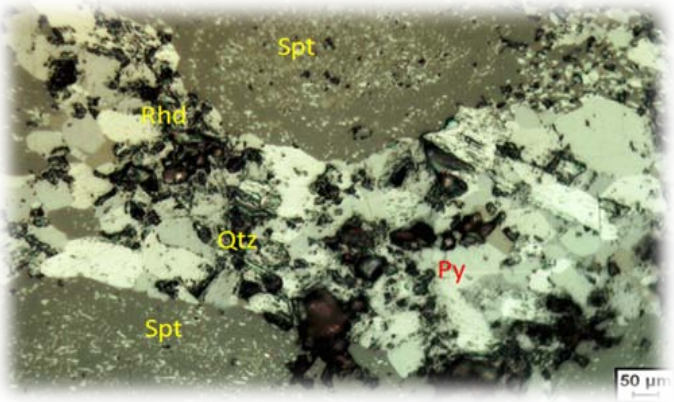


Figure 7 : Ore microphotograph showing rhodonite (Rhd), spessartite (Spt), quartz (Qtz) as a metamorphic mineral assemblage in the metamorphosed ores from Ukwa Mine, Balaghat district, M.P India

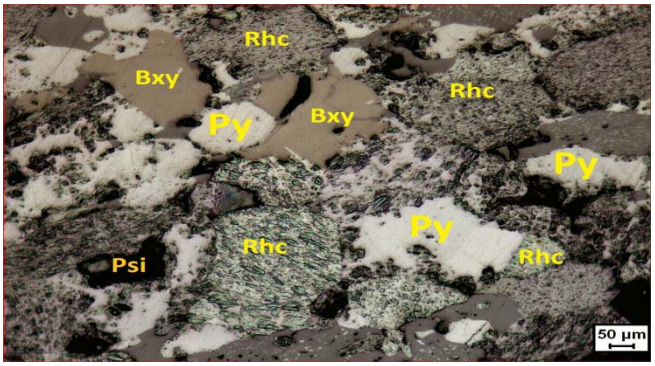


Figure 8 : Ore microphotograph showing bixbyite (Bxy), Rhodhocrosite (Rhc) and pyrolusite (Py) as a metamorphic mineral assemblage in the metamorphosed ores from Ukwa Mine, Balaghat district, M.P India

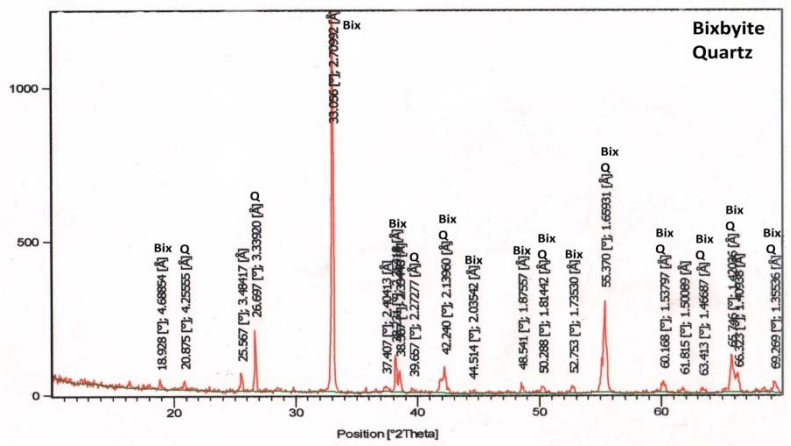


Figure 9 : Showing 2θ position of bixbyite and quartz (Bharweli mine, Balaghat district, M.P.)

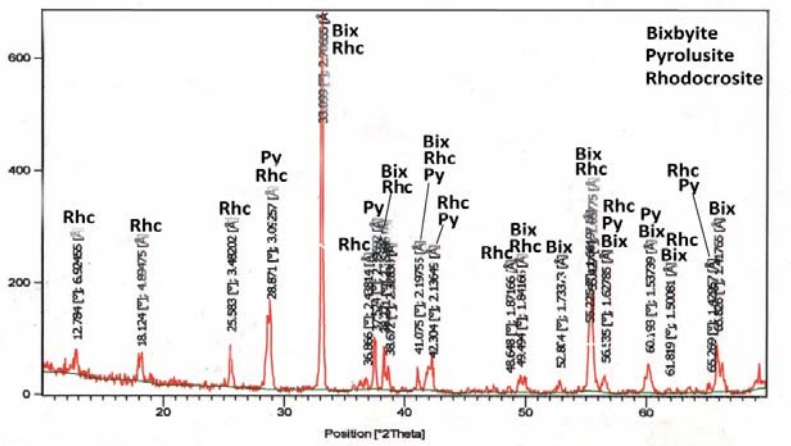


Figure 10 : Showing 2θ position of bixbyite, pyrolusite and Rhodochrosite(Ukwa mine, Balaghat district, M.P.)

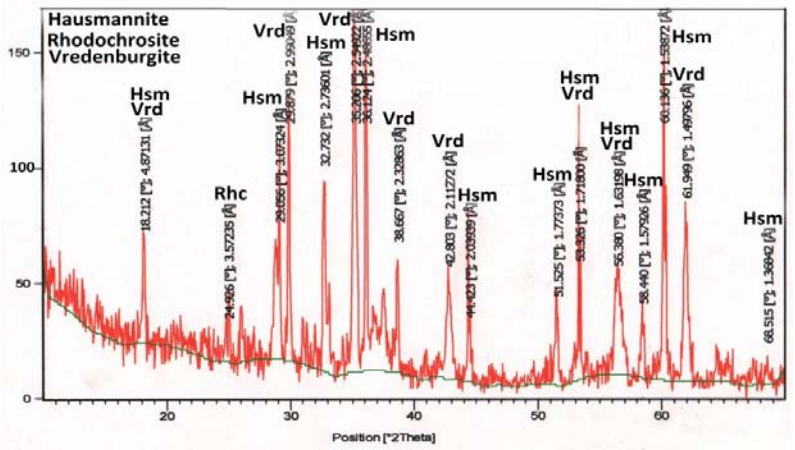


Figure 11 : Showing 2θ position of hausmannite, rhodochrosite and vredenburgite(Tirodi mine, Balaghat district, M.P.)

VII. Conclusions

Braunite forms at a very low temperature, appearing in the chlorite zone of regional metamorphism, and it continues in stable form right up to the sillimanite zone. Schneiderhohn (1931) and Dunn (1936) considered bixbyite as a high temperature mineral appears first in biotite zone and also appears in the sillimanite and almandine zone in the Balaghat. It shows records, at places, of conversion to hausmannite, and a second generation of this mineral is also found to have been formed as conversion product in the cleavages of the latter in ore bodies of sillimanite zone in Tirodi areas. Bixbyite continues up to the sillimanite zone along with braunite and other high temperature lower oxides of manganese. Vredenburgite, free hausmannite and free jacobsite appear in the sillimanite zone. Hollandite appears in the almandine zone, apparently at the cost of psilomelane (Richmond and Fleischer, 1942; Wadsley, 1950) and continues to the sillimanite zone. In waning stages of metamorphism, bixbyite in all zones converts to second generation braunite. Magnetite and primary pyrolusite formed everywhere in the waning stage.

The phase equilibrium studies of systems involving magnetite, jacobsite, vredenburgite and hausmannite considerable data suggests regarding the formation and stability range of the minerals. The formation of jacobsite is dependent on two major factors, viz., (i) enough iron in the bulk composition and (ii) adequate temperature for the stability of manganese and iron in Mn_3O_4 and Fe_3O_4 stage. Van and Keith (1958) observed that the compositional range of jacobsite increases with higher temperature. In metamorphic manganese ores, jacobsite free of hausmannite lamellae would form in fairly high grade of metamorphism when the composition limit does not extend to the vredenburgite field or when the temperature never reaches for the mix crystal (metastable vredenburgite) to form. The presence of vredenburgite ensures high temperature in the range of approximately 500° to 700°C or higher (Mason, 1943b), a bulk composition rich in manganese (vredenburgite field) and a sufficiently slow cooling for the intergrowths to form. Wherever the delicate intergrowths of jacobsite and hausmannite are retained, it is evident that there was no further recrystallization. The presence of discrete grains of hausmannite, not oriented in the crystallographic directions of jacobsite in metamorphic ores, would indicate a bulk composition low in iron and a high temperature of formation. It has been shown by laboratory experiments that higher oxides of manganese such as cryptomelane and pyrolusite convert to hausmannite at high temperature (McMurdie and Golovato, 1948; Delano, 1950; Faulring,et. al.,l960; etc.). In most of these cases, however, the Mn_3O_4 state (hausmannite) is attained through the Mn_9O_3 state (bixbyite). When hausmannite is present as discrete grains in addition to its presence as lamellae in associated vredenburgites, it apparently either indicates presence of excess Mn_3O_4 which could not enter into vredenburgite and crystallised independently, or that part of the exsolved hausmannite had segregated outside jacobsite after exsolution. This may indicate that subsequent to the exsolution of hausmannite in jacobsite, further recrystallization ensued, due to which the intergrowth was destroyed and the two minerals recrystallized as discrete grains.

In a very slow rate of cooling also the exsolved hausmannite would tend to migrate to the borders or interstitial spaces of jacobsite rather than to stay confined in them. The presence of hausmannite alone, in the absence of jacobsite, evidently reflects a high temperature of formation and a bulk composition rich in manganese but poor in iron.

The phase-equilibrium studies involving manganese, iron and silica and from investigations on different natural mineral assemblages of manganese

ores of various metamorphic grades, it has been possible to throw some light on the formation and phase transformation of some important manganese minerals with change in temperature and possible variation of oxygen partial pressure. With the onset of metamorphism, and consequent increase in temperature, the higher oxides of manganese with dominant Mn^{4+} in the sedimentary deposits, transform to the Mn_2O_3 state and combine with the available silica to form braunite. The stability range of braunite being very wide, it can form as a transformation product of MnO_2 in low grade metamorphism and can continue right up to the highest grade. Bixbyite, on the other hand, appears sometime later than braunite at a higher temperature and though its temperature of formation has been determined in the laboratory as around 500°C (Klingsberg and Roy, 1959; Mason, 1943b) it can appear in biotite zone, at a lower temperature, in natural metamorphic process. Bixbyite, in most cases, is accompanied by hollandite which is also a transformation product of psilomelane formed in elevated temperature condition (Richmond and Fleischer, 1942; Wadsley, 1950). The association of braunite, bixbyite and hollandite (in the absence of jacobsite, hausmannite and vredenburgite) continues to the almandine zone (Bharweli-Ukwa area).

The manganese oxide mineral assemblages and their paragenesis in higher metamorphic zones were related to the phase transformations shown in the phase-equilibrium diagrams given by Mason (1943b) and Muan and Somiya (1962). The coexistence of bixbyite, metastable vredenburgite (later exsolved to two phases) and hausmannite correspond to the isobaric binary invariant situation at 932°C (laboratory condition, in air) in the phase-equilibrium diagram furnished by Muan and Somiya (1962). With lowering of temperature, a small amount of bixbyite (2-3 %) may form either as exsolution or conversion product in hausmannite at Tirodi areas. The stability of this bixbyite will, however, depend upon the oxygen partial pressure prevalent at that time. With lowering temperature, the two-phase region of vredenburgite is reached and hausmannite lamellae exsolved in jacobsite-host. The vredenburgite thus formed may retain its intergrowth, or may recrystallize leading to the formation of discrete grains of jacobsite and hausmannite. Hollandite, manganite and sometimes primary pyrolusite form in lowering temperature condition in the waning stage.

After detailed studies and discussion, the author observed that a definite trend of formation and transformation of manganese oxide minerals with increasing of temperature in metamorphic condition. Though definite or absolute temperature of formation cannot always be predicted when other supporting data regarding oxygen partial pressure etc. are lacking, the sequence of formation and transformation of the minerals is more or less constant.

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- Paper Title should be of Font Size 24 with one Column section.
- Author Name in Font Size of 11 with one column as of Title.
- Abstract Font size of 9 Bold, "Abstract" word in Italic Bold.
- Main Text: Font size 10 with justified two columns section
- Two Column with Equal Column with of 3.38 and Gaping of .2
- First Character must be three lines Drop capped.
- Paragraph before Spacing of 1 pt and After of 0 pt.
- Line Spacing of 1 pt
- Large Images must be in One Column
- Numbering of First Main Headings (Heading 1) must be in Roman Letters, Capital Letter, and Font Size of 10.
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You can use your own standard format also.
Author Guidelines:

1. General,

2. Ethical Guidelines,

3. Submission of Manuscripts,

4. Manuscript's Category,

5. Structure and Format of Manuscript,

6. After Acceptance.

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Research letters: The letters are small and concise comments on previously published matters.

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(b) A brief Summary, "Abstract" (less than 150 words) containing the major results and conclusions.

(c) Up to ten keywords, that precisely identifies the paper's subject, purpose, and focus.

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(e) Resources and techniques with sufficient complete experimental details (wherever possible by reference) to permit repetition; sources of information must be given and numerical methods must be specified by reference, unless non-standard.

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(h) Brief Acknowledgements.

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References

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30. Think and then print: When you will go to print your paper, notice that tables are not be split, headings are not detached from their descriptions, and page sequence is maintained.

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Key points to remember:

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- Please note the criterion for grading the final paper by peer-reviewers.

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- To the point depiction of the research
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- Present a justification. Status your particular theory (es) or aim(s), and describe the logic that led you to choose them.
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- Describe the method entirely
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures
- Simplify - details how procedures were completed not how they were exclusively performed on a particular day.
- If well known procedures were used, account the procedure by name, possibly with reference, and that's all.

Approach:

- It is embarrassed or not possible to use vigorous voice when documenting methods with no using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result when script up the methods most authors use third person passive voice.
- Use standard style in this and in every other part of the paper - avoid familiar lists, and use full sentences.

What to keep away from

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings - save it for the argument.
- Leave out information that is immaterial to a third party.

Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part a entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Carry on to be to the point, by means of statistics and tables, if suitable, to present consequences most efficiently.You must obviously differentiate material that would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matter should not be submitted at all except requested by the instructor.

Content

- Sum up your conclusion in text and demonstrate them, if suitable, with figures and tables.
- In manuscript, explain each of your consequences, point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation an exacting study.
- Explain results of control experiments and comprise remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or in manuscript form.

What to stay away from

- Do not discuss or infer your outcome, report surroundings information, or try to explain anything.
- Not at all, take in raw data or intermediate calculations in a research manuscript.
- Do not present the similar data more than once.
- Manuscript should complement any figures or tables, not duplicate the identical information.
- Never confuse figures with tables - there is a difference.

Approach

- As forever, use past tense when you submit to your results, and put the whole thing in a reasonable order.
- Put figures and tables, appropriately numbered, in order at the end of the report
- If you desire, you may place your figures and tables properly within the text of your results part.

Figures and tables

- If you put figures and tables at the end of the details, make certain that they are visibly distinguished from any attach appendix materials, such as raw facts
- Despite of position, each figure must be numbered one after the other and complete with subtitle
- In spite of position, each table must be titled, numbered one after the other and complete with heading
- All figure and table must be adequately complete that it could situate on its own, divide from text

Discussion:

The Discussion is expected the trickiest segment to write and describe. A lot of papers submitted for journal are discarded based on problems with the Discussion. There is no head of state for how long a argument should be. Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implication of the study. The purpose here is to offer an understanding of your results and hold up for all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of result should be visibly described. Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved with prospect, and let it drop at that.

- Make a decision if each premise is supported, discarded, or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."
- Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work
- You may propose future guidelines, such as how the experiment might be personalized to accomplish a new idea.
- Give details all of your remarks as much as possible, focus on mechanisms.
- Make a decision if the tentative design sufficiently addressed the theory, and whether or not it was correctly restricted.
- Try to present substitute explanations if sensible alternatives be present.
- One research will not counter an overall question, so maintain the large picture in mind, where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

- When you refer to information, differentiate data generated by your own studies from available information
- Submit to work done by specific persons (including you) in past tense.
- Submit to generally acknowledged facts and main beliefs in present tense.

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Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

INDEX

A

Almandine · 42, 46, 48, 50, 62, 64
Amelioration · 22
Assemblages · 44, 50, 52, 54, 55, 63, 64

C

Concomitant · 53
Conflict-Ridden · 11
Cryptomelane · 48, 50, 51, 55, 56, 58, 63, 66

D

Debris · 23

E

Enacting · 16
Epileptic · 10

F

Fugacity · 52, 53

H

Harnessed · 10
Hausmannite · 42, 43, 50, 51, 52, 53, 54, 58, 62, 63, 64
Hollandite · 42, 43, 50, 55, 56, 64, 65
Hoplocerambyx · 28

M

Mitigation · 10, 22, 23, 24, 26, 29, 38

P

Pelitic · 44, 46, 48

R

Regime · 16
Resilience · 17, 23

S

Sporadic · 54
Strontium · 56

T

Terrain · 3, 65

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