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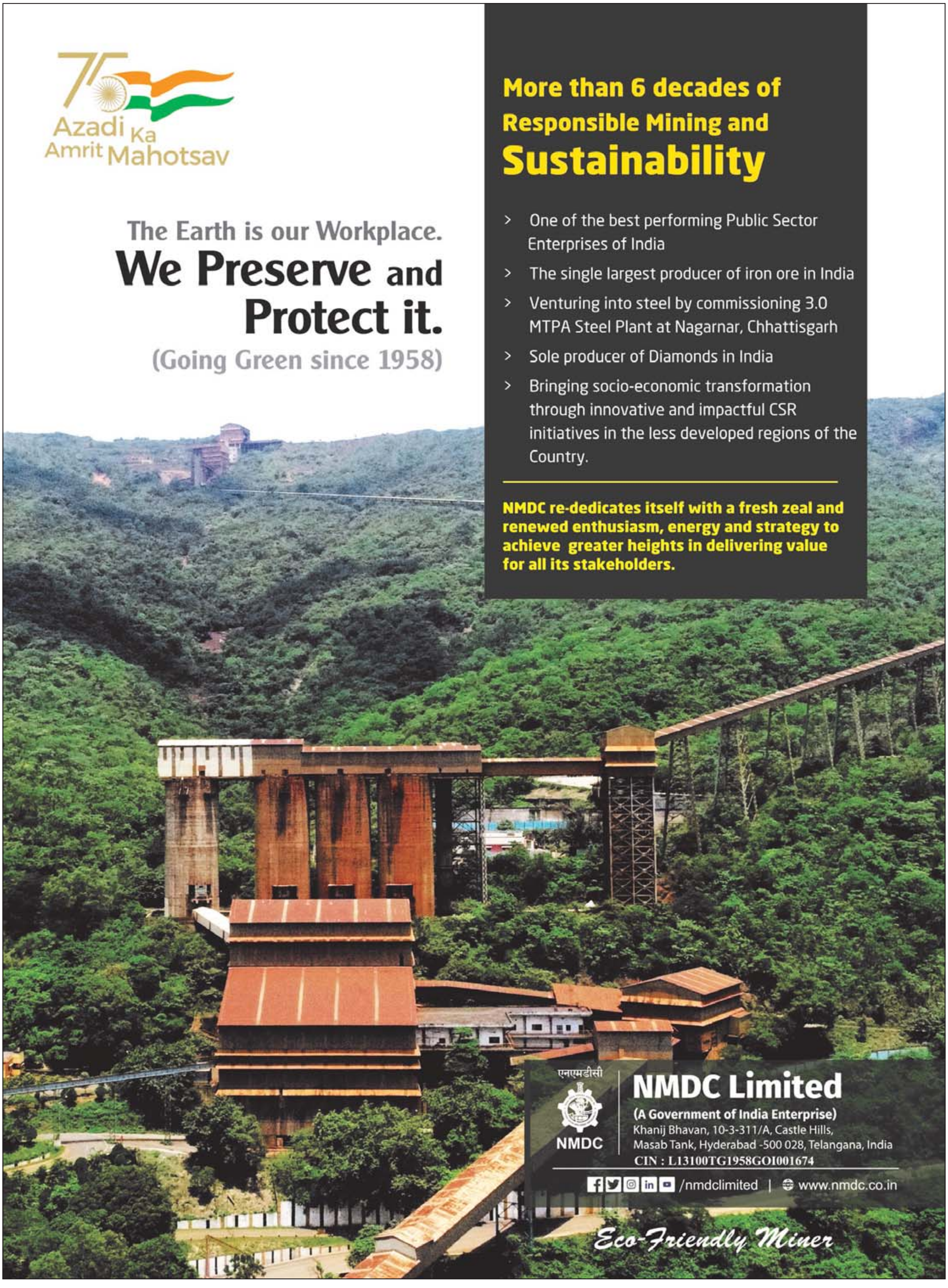
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this issue contains...

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President's Message......

Dear Members,

Greetings…

I wish to put forth the activities undertaken by our Association in the preceding month.

I am happy to share with you the information of some Chapters celebrating ***May day*** at their locations. It was the day to salute the hard work and dedication of strong-willed workforce in all industries.

A focused group discussion was organised by Rajasthan -Jaipur Chapter on 6^{th} May at Mining Welfare centre, with Prof. N.K. Jain of IIM, Nagpur as the primary speaker. It was held in both Physical and Virtual modes. Participation was high and some great insights emerged.

Rajasthan-Udaipur Chapter, in association with Vigyan Samiti, celebrated the National technology day on 11^{th} may 2023 at Vigyan Samiti, Udaipur.

I am extremely happy to note that the MEAI ***Professional Development program (MPDP) -III*** (Online) was inaugurated by ***Sri. B.R.V. Susheel Kumar, Director, Govt of Telangana*** as the Chief Guest, on 5^{th} May 2023. In all 41 Professionals enrolled for this session and participants represented different organisations from mining and allied industries. It was successfully completed on 21^{st} May. 16 eminent faculties shared their knowledge on 22 topics during the programme. ***Sri. Ajit Kumar Saxena, Chairman Cum Managing Director, MIOL limited*** was present as the Chief Guest in the Valedictory Function on 21^{st} May 2023 and encouraged all Participants & our members to use this platform to improve their skill sets. We are very much thankful to Sri. B.R.V. Susheel Kumar, Sri. Ajit Kumar Saxena, Sri. Deepak Vidyarthi, Sri. M.M. Abdulla, all faculty members, Organisations, Participants etc for their support & feedback.

As a part of MEAI TECH SERIES (MTS) monthly online program, a talk on ***"Environmental Clearance of an iron ore Project-a Case Study"*** was delivered by ***Mrs. Manorama Mahapatra***, on 26^{th} May 2023 as MTS-11. The MTS program is an ongoing program, which is held every month. Request all the mineral industry professionals to utilise this opportunity.

I am happy that ***the 8th Council meeting, AGM, and Award function*** is planned to be held along with an ***International Conference on Mining Vision 2047*** from 25^{th} August to 27^{th} August at Ahmedabad by MEAI Ahmedabad Chapter. Request everyone to join the same.

Regards,

K. MADHUSUDHANA
President

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EDITOR'S DESK

Dr. P.V. Rao
Editor, MEJ

Sharing below an abridged version of a Bloomberg article entitled "Why the Fight for 'Critical Minerals' Is Heating Up", published on May 5 2023.

Over more than a century, oil companies have developed a vast industrial network to extract, refine and deliver their product to customers around the world. For more than a decade, China has tackled sourcing the materials needed to build an alternative, less carbon-intensive economy successfully making it the undisputed leader in the "critical minerals" used in electric vehicle batteries, solar panels and wind-turbine magnets.

Nations have long sought to protect supplies of materials they deem vital to their industrial and military capabilities. About 50 metallic elements and minerals currently meet those criteria in the US and European Union. Most of them were chosen for their role in building the infrastructure required to reduce carbon emissions blamed for climate change, a mission that is backed by hundreds of billions of dollars in subsidies and tax breaks. Those materials include lithium, graphite, cobalt, nickel and manganese (used predominantly in EV batteries), silicon and tin (used in EVs, smart grids, power meters and other electronics), rare earths (used in wind-turbine magnets, EVs) and copper (used in grids, wind farms, EVs).

While many critical minerals can be found in a raw state in large quantities across the globe, extracting and refining them into a usable form can be costly, technically challenging, energy intensive and polluting. China dominates the entire value chain in many of these products, accounting for more than half of the world's production of battery metals including lithium, cobalt, and manganese, and as much as 100% of rare earths. Even in less rarefied metals such as copper, forecasts of massive demand growth have sparked a realization that there might not be enough to go around. Over-dependence on supplies from any single country is something that manufacturers try to avoid as it leaves them exposed when that country's industrial output is disrupted by events like power crises, pandemics, social unrest or political alliances.

As China's economic growth accelerated, domestic demand for industrial commodities began to far outstrip local reserves. It responded with huge investments in mining assets overseas and came gradually to dominate the refining and processing of virtually every industrial commodity, as well as a host of obscure byproducts like tellurium, gallium and germanium that are needed in products such as solar panels, lasers, night-vision goggles and computer chips. Today it is the leading producer of 20 critical raw materials, as measured by its share of mined or refined production globally. In the case of the rare earth element dysprosium, it is responsible for 84% of mined supply and 100% of refined production, according to an EU analysis. Though it mines only a small amount of cobalt and nickel but it is by far the largest producer of refined forms of the metals. Chinese companies have been investing heavily in cobalt and nickel mines in countries such as Congo and Indonesia.

The Inflation Reduction Act passed in 2022 by the US was aimed at helping it meet its climate goals through investments in renewables and EVs, curb prices of the raw materials needed for the transition and ease reliance on unreliable or hostile overseas suppliers. The EU's Critical Raw Materials Act launched in March 2023 aims to ease financing and permitting for new mining and refining projects and strike trade alliances to reduce the bloc's dependence on Chinese suppliers. The US and Europe are also looking to set up a "buyers' club" to strike supply deals and investment partnerships with producing nations. With China and other nations with fast-growing economies increasingly restricting exports of industrial raw materials, the US and the EU are rushing to build their own refining capacity. Nevertheless, sourcing the mined product required is more problematic.

Even before any direct response to this from Beijing, Chinese companies look set to consolidate their grip on key metals such as nickel and cobalt. In lithium, while the US is building out supply networks with free-trade partners such as Canada and Australia, China is consolidating its relationships with African nations that are expected to be among the world's biggest producers of the metal by the end of the decade. In rare earths, there are signs that China may seek to forestall the west's efforts to build new mining and processing capacity by restricting exports of key technology and equipment.

- Editor

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NEWS FROM THE MINING WORLD

Centre plans to make Chhattisgarh's Gevra Asia's largest coal mine

The Gevra Mega project is currently the largest coal-producing mine in India and is in second position in the Asia-pacific region.

The Centre plans to increase the capacity of the Gevra Mega project in Chhattisgarh of South Eastern Coalfields (SECL) from 50 million tonne of coal production in a year to 70 million tonne, making it Asia's largest coal-producing mine in Asia.

The Gevra Mega project is currently the largest coal-producing mine in the country and is in second position in the Asia-pacific region.

On his two-day visit to Raipur, Coal Secretary Amrit Lal Meena held a high-level review meeting with top officials of the Chhattisgarh government.

In a statement released on Saturday, the coal ministry informed that the meeting deliberated on issues related to SECL's operations including environmental clearances, forest clearances, land acquisition, cooperation from the state government for rehabilitation and resettlement for SECL's mega projects like Gevra, Dipka and Kusmunda.

The need for time-bound completion of the projects with effective coordination with the state government and other stakeholders was especially emphasised by the coal secretary.

The meeting was focused on the evacuation of coal from the Korba and Mand-Raigarh coalfields. Senior functionaries from both SECR and SECL were also present during the discussions.

The officials also discussed issues pertaining to SECL's coal dispatch, availability of railway rakes, rail projects of SECL, among others, in detail.

The Centre plans to make the Gevra Mega project into Asia's largest coal-producing mine. The Gevra Mega project is owned by SECL. SECL is a state-owned miniratna company and Coal India is its parent company.

Indonesia's Sangatta Mine in East Kalimantan, was the largest surface coal-producing mine in the Asia-Pacific region, producing approximately 49.2 million tonnes of coal and an estimated 51.4 million metric tons per annum (mmtpa) of Run-of-Mine (ROM) in 2021.

BS Web team / May 21 2023

Govt planning to introduce amendment bill for minerals mined offshore

The government is likely to introduce an amendment bill, which seeks to provide auction of minerals mined offshore, in the next Parliament session, sources said.

The government is likely to introduce an amendment bill, which seeks to provide auction of minerals mined offshore, in the next Parliament session, sources said.

"The hurdle is that the original Act for offshore mining does not provide for auctions of minerals. The auction is the policy now. So the Act needs to be amended," the sources said.

The objective behind the move is to use the national wealth in the sea for the use of people of the country, they pointed out.

The Offshore Areas Mineral (Development and Regulation) Act was enacted in 2002.

However, not even a single rock could be mined out from the sea-bed mainly due to pending litigations.

"The consultations to amend the act are over and a bill is likely to be introduced in the forthcoming Monsoon session of Parliament," they said.

The amendments will help in realizing the natural wealth which lies with the country along its coast.

Press Trust of India / New Delhi

Investment opportunity of $30 bn in petrochemical sector: Hardeep Puri

India offers investment opportunity of $30 bn in petrochemical sector over next decade as world's third largest energy consumer looks to meet growing demand, Oil Minister Hardeep Puri said.

India offers investment opportunity of USD 30 billion in the petrochemical sector over the next decade as the world's third largest energy consumer looks to meet growing demand, Oil Minister Hardeep Singh Puri said on Friday.

Addressing Asia Petrochemical Industry Conference 2023 here, the minister highlighted that the size of the Indian chemical and petrochemcial sector is around USD 190 billion and it is poised for transformational growth.

He rued that the per capita consumption is still low as compared to developed economies.

Puri noted that the petrochemical sector has made a significant progress in recent years, becoming one of the largest producers of petrochemical products in the world.

"The market size of the Indian chemical and petrochemical sector I'm told is about USD 190 billion. The per capita consumption of various chemical products and segments is significantly lower compared to the developed economies. And this gap offers substantial space for demand growth and investment opportunities," he said.

The minister said the chemicals and petrochemicals demand in India is expected to nearly triple and is expected to reach USD 1 trillion by 2040.

Press Trust of India, New Delhi | May 19 2023

➠ Indian steelmakers look for government support to go the green way

Transition calls for large investment but demand for and premium on eco-friendly steel remains dull.

Indian steelmakers are stressing the need to incentivise 'green steel' as they invest to cut down on carbon emissions.

Green steel, or low-carbon emissions steel, is at a nascent stage globally, with companies undertaking pilot projects. Large-scale investments are required for the transition but with demand and "green premium" in question in the domestic market, steel firms are looking for government support.

In India, the regulatory environment isn't yet incentivising the transition, T V Narendran, managing director and chief executive officer, Tata Steel, said.

"It's moving in that direction, but today, if my CO_2 is lower at the Jamshedpur plant than the Meramandali plant, it does not get any advantage," he said. "And customers don't pay us more for the steel that comes out of Jamshedpur than Meramandali. The whole ecosystem has to evolve for this transition to happen faster."

In Europe, where Tata Steel has a large operation, it's more definitive. "About 40-50 per cent of our footprint in Europe has to go green by 2030, the rest by 2035," Narendran said. "The capex we spend will partly come from us and hopefully, there will be some support from the government. And partly, the customers will pay more."

The government's proactive support is a must to accelerate the green steel journey, added ArcelorMittal Nippon Steel India CEO Dilip Oommen said. "The journey to low-carbon emissions steel is in the right direction, albeit gradual."

"The right set of policy and regulatory frameworks along with support in terms of incentives for both producers and consumers of green steel will go a long way in driving low-carbon economic development and ultimately achieving the ambitious net-zero goal by 2070," Oommen said.

He also pointed out that all major steel players, which have announced huge capex plans to achieve the 300 MTPA (million tonnes per annum) target by 2031 and beyond, were actively exploring the potential for renewable energy integration into the supply chain.

Saarloha Advanced Materials, a Kalyani Group company, started producing 'green steel' under the 'Kalyani Ferresta' brand last October, but demand and premium for the product are yet to pick up.

"We require government intervention for demand creation," R K Goyal, managing director of Kalyani Steels and director of Saarloha said. "In all government and public sector purchases, a certain quantity should be specified as 'green' with less than 0.2 tonne of CO_2 emission per tonne of crude steel. There should be some incentive."

Steel companies in other geographies are getting government support for the transition. The European Union has granted funds to support capex-related activities, Hetal Gandhi, director–Research, CRISIL Market Intelligence and Analytics, said.

"Additionally, CBAM (carbon border adjustment mechanism) would protect local mills producing green steel by taxing CO_2 emissions, partially making up for the additional production cost," she explained.

"Similarly, the US government has initiated a $6.3-billion Industrial Demonstration Programme, which will provide grants of up to 50 per cent of the cost to projects that aim to cut emissions," Gandhi said, adding, "Canada has introduced the Decarbonisation Incentive Programme (DIP) to incentivise the decarbonisation goals of its industrial sector,"

In India, the Union steel ministry has set up 13 task forces to identify action points for each aspect of green steel production including raw materials, technology and policy frameworks.

In the long term, it is policy interventions, financial support and infrastructure development that would push deep decarbonisation of the steel industry, Alok Sahay, secretary general, Indian Steel Association, said.

"Viability gap funding is the right way to help decarbonise the steel industry. This has to be dovetailed with generating demand for low-emission carbon steel through government procurement to begin with," Sahay added.

Demand for low-carbon steel is yet to pick up in India but developed nations have steeper net-zero targets, and they are already asking about emissions.

A spokesperson of Jindal Stainless said they had started receiving enquiries about green initiatives from international customers. "They are mostly enquiring about the company's green initiatives and emissions target."

Global-facing steel companies have net-zero targets that are ahead of India's target year of 2070. As they add capacity – mostly through the blast furnace route – firms are working on various options to lower carbon emissions. Since these options are likely to entail significant investment, they're looking for government support for faster transition.

Ishita Ayan Dutt, Kolkata, BS | May 16 2023

Coal India net profit rises 62% to record Rs 28,125 crore in FY23

Q4 profit slips marginally, Board declares Rs 4 per share dividend

National miner Coal India's (CIL's) profit for the financial year 2023-24 increased 62 per cent year-on-year (YoY) to an all-time high of Rs 28,125 crore, riding on the back of high production and sale of coal.

The company's profit during the fourth quarter, however, slid by 18 per cent to Rs 5,528 crore, owing to an increased provision towards wages, CIL said.

"CIL lifted its profit into higher orbit despite the company capping its coal prices for over the past five years amidst rising input costs, especially diesel and explosives, and increased wage cost due to provisioning in the accounts," CIL said in a public statement.

The company's net sales were the highest ever for the fourth quarter as well as for the entire FY23. Net sales at Rs 35,161 crore in Q4 were up 17 per cent over the year-ago period. For FY23, CIL's net sales was Rs 1.27 trillion, a jump of 27 per cent compared to Rs 1 trillion in FY22, it said.

The company's board that met on May 7 recommended the payment of a final dividend of Rs 4 per share. Earlier in two tranches in FY23, a total dividend of Rs 20.25 per share was already paid out, it said.

In FY23, CIL touched a record coal production of 703 million tonne (mt). It is aiming to produce 780 mt in FY24. Higher volume sales by 17.34 mt and better average realisation under fuel supply agreement (FSA) resulted in a net impact of around Rs 3,879 crore in Q4, CIL said.

The sale of coal under FSA increased to 167.45 mt in Q4 compared to 150.11 mt in the year-ago quarter. Realisation per tonne of coal under FSA increased 6 per cent to Rs 1,550 per tonne in Q4 from Rs 1,470 a tonne in Q4FY22.

Through e-auction sales, the company sold 16.40 mt of coal, which is lower by 41 per cent over FY22. The realisation per tonne of coal was Rs 4,526 under auction segment in Q4 against Rs 2,434 in the same quarter of FY22. The jump was Rs 2,092 per tonne or 86 per cent.

The realisation per tonne of coal under e-auction was Rs 4,841 against Rs 1,879 per tonne in FY22. The same in case of FSA sales was Rs 1,475 compared to Rs 1,406 of FY22.

Shreya Jai, New Delhi, BS | May 07 2023

Congo President heads to China amid mining contract negotiations

Democratic Republic of Congo President Felix Tshisekedi will visit China next week as the two nations look to conclude the re-negotiation of a $6.2 billion mineral-for-infrastructure deal, people with direct knowledge of the trip said.

It's the president's first visit to the country, Congo's biggest trading partner. The two nations did $21.7 billion of trade in 20.

The trip comes as Tshisekedi prepares for elections scheduled for December. Spokespeople for the president and the government didn't respond to text messages requesting comment. China's Foreign Ministry announced on Friday that Congolese Foreign Minister Christophe Lutundula would visit China May 21-24.

Tshisekedi is scheduled to travel to Beijing, Shanghai and Shenzhen May 24 through May 29 with a contingent of government officials including his ministers of mines, hydropower and defense. Besides meeting with counterpart Xi Jinping, Tshisekedi is also scheduled to visit a number of battery, energy, mining and tech companies.

China is the primary destination for most of Congo's copper and cobalt, a key ingredient in electric-vehicle batteries. The central African nation produces 70% of the world's cobalt and was tied with Peru as the second-biggest source of copper last year.

In 2008, Congo signed a deal with Chinese state companies to finance $3 billion of infrastructure projects using the proceeds from a $3.2 billion copper and cobalt mine. The landmark agreement was signed at a time when Congo was struggling to secure financing after years of war.

'Bad contract'

In January, Tshisekedi told Bloomberg the contract was "badly drawn up" and that Congo had "derived no benefit from it." The president said the deal needed to be "rebalanced."

While the mine is pumping out metal, the Chinese partners have only disbursed about $822 million of infrastructure funding over 14 years, the country's inspector general said in a report in February.

The watchdog accused the Chinese companies of financial malfeasance, including transfer pricing and dumping, and called for them to be fined $100 million for breaching capital controls under the nation's mining code by not repatriating more than $2 billion in export revenue.

The inspector general called on the Chinese partners to release $1 billion in infrastructure funding this year and amend the contract to ensure half of future infrastructure contracts go to Congolese companies.

China's embassy dismissed the report's conclusions at the time.

Royalty billions

Congo is also negotiating a final deal with China's CMOC Group Ltd., which is in a dispute with its partner, state-owned Gecamines, over the Tenke Fungurume copper and cobalt mine. Gecamines says CMOC owes billions in royalties and a court-appointed administrator blocked Tenke's exports last July.

While CMOC and Gecamines have agreed on the outlines of a resolution, they've yet to sign a final agreement, Gecamines Chairman Guy-Robert Lukama told Bloomberg Thursday in an interview in Kinshasa, Congo's capital. In the interim, the joint venture has re-started exports of copper mined in 2022, but is still blocked by the finance ministry from exporting cobalt, he said.

CMOC didn't respond to emailed questions on Friday. Officials from Gecamines, which is also a partner in the minerals-for-infrastructure contract, are also traveling to China.

Bloomberg News | May 19, 2023

➠ Chile's new lithium policy a boon for other producers

A decision by Chile, the world's no. 2 lithium producer, to tighten control over the key battery metal sector has left many in the industry wondering what the announced state-led public-private model will look like and who, if anyone, will benefit from it.

The lack of specifics on how much ownership the government will demand from companies and the pushback President Gabriel Boric could face when trying to create a national lithium company, add to the uncertainties Chile's new policy has created.

For Joe Lowry, known in mining circles as "Mr. Lithium" due to his decades of experience in the sector, says that the lack of specifics in Chile's policy could be a boon to other producing countries, with Canada being in a particularly advantageous place.

According to Mining Intelligence, Canada currently has nearly 40 lithium projects in different stages of development, but only two operating mines — Sayona Mining's (ASX: SYA) North American Lithium (NAL) in Quebec and Sinomine Resource Group's Tanco mine in Manitoba. The latter also produces cesium and tantalum.

NAL, in which Piedmont Lithium (NASDAQ:PLL) has a 25% stake, restarted production only in March while the Tanco mine reopened in December.

In its critical minerals strategy released in December, Ottawa listed lithium as one of the top six critical minerals, along with copper, nickel, cobalt, graphite and rare earths, due to its importance in the green technology sector.

"I believe that Canada, with its vast hard rock lithium assets, will become the Australia of North America in terms of lithium supply," Lowry says. "But the more capital that lands in North America's lithium industry, the worse it is for Chile".

Best cost structure

Lowry, who is also President of Global Lithium LLC, believes that Chile has the best cost-structure to produce lithium in the world.

"[It] not only has giant reserves with high concentration of lithium, but it also has a geographical advantage — the driest desert in the world, where evaporation ponds work best," he says.

Chile to nationalize its lithium industry

Evaporation ponds in Atacama's Salt Flat, Chile. (Image courtesy of SQM.)

The problem, he notes, is that the strategy unveiled last week could slow the development of the country's local industry.

The expert, who has seen the global lithium sector grow from a $200 million market when he entered the game in 1990 to $1 billion by 2015 and over $40 billion today, expects supply will continue to disappoint even as governments and automakers in the US and Europe are investing heavily in the sector.

"[This is why] Chile is in a great position and it can remain there for at least two decades, but it needs to calm investors by providing details of how the new model will work," he says.

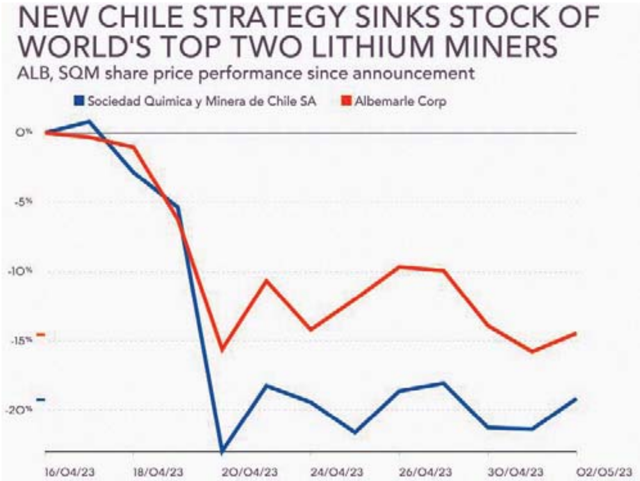
Chile policy resembles those of Bolivia and Mexico

For the North Carolina-based consultant, who regularly draws mining industry heavyweights to his podcast, Chile could easily recover its world leader position in the lithium market, lost to Australia in 2018, with the right policies.

"If you go back to early 2016, Australia had only one lithium mine in operation, while Chile was the dominant world producer. All of that has turned around in the last five to seven years and it's a shame. It didn't have to happen," Lowry said.

Boric's move places Chile closer to fellow Latin American countries Bolivia and Mexico, which have discouraged investors by imposing greater state control, though Chinese groups may still be keen to fill the gap. "But is that what Chile wants?", Lowry wonders.

The world's two top producers will be forced to operate in a vastly different landscape once the current regime changes – since Boric's announcement, the value of the two lithium miners operating in Chile — US-based Albemarle (NYSE: ALB) and Chile's SQM (NYSE: SQM)— has dropped by billions of dollars.



Source: Bloomberg

Both companies have recently announced plans to expand operations elsewhere and experts say they wouldn't be surprised if they announce further geographical diversification.

Albemarle is in pursuit of Australia's Liontown Resources (ASX: LTR), while SQM is advancing the $1.4 billion Mt Holland hard-rock project, also in Australia, with local lithium conglomerate Wesfarmers (ASX: WES).

In a recent commentary, German Mineral Resources Agency's senior analyst Michael Schmidt wrote that regulatory uncertainties in Chile, Bolivia and Mexico will mean that about 63% of global lithium supply will come from rocks and not from brines by 2030.

The forecast shows how the power dynamics of the lithium industry continue to change rapidly. "The top six lithium producers can sell all of their production today, without having to sell Tesla a gram. That wasn't true six years ago," Lowry says.

Brines production share evaporates

Analysts from Fastmarkets believe that, if Chile fails to capitalize on the lithium boom, it would fall from the world's second-largest lithium producer last year to fourth in 2030 after China, Australia and Argentina. They forecast the country's share of production would shrink from almost a third to 12%.

While Boric needs approval from Congress for the creation of a national lithium company, he has the power to enact other elements of the policy. This is why he has enlisted two other state-owned companies, Codelco, the world's largest copper producer, and state miner Enami, to determine how the private-public partnerships will operate.

Codelco will be initially in charge of negotiating a stake for the state in Albemarle's and SQM's operations. Enami, in turn, will sign up partners for new contracts. Their roles will then be undertaken by the dedicated national lithium company, with a mandate to develop the industry into a pillar for Chile's economy while protecting its environment.

Previous efforts to bring more actors into the country's lithium sector have failed, with the most recent case being the one of Chinese automaker ByD Co, whose 80,000-tonne lithium contract was revoked following objections from a local governor.

Together with the lack of details in Chile's lithium policy, expanding lithium mining in the Atacama desert will likely attract opposition from environmental groups. This, analysts agree, could make the process of awarding contracts more difficult and lengthier.

Asked about what he would say to Boric if he asked him for advice, Lowry does not hesitate: "I would tell him to put [the lithium policy announcement] back in the oven and finish the baking job".

Cecilia Jamasmie, Mining.Com | May 3, 2023

Australia hands out critical minerals grants

Australia has rolled out a series of grants to critical minerals companies hoping to speed up development of a battery chemical industry and will soon announce details of a national industry strategy, its resources minister said on Thursday.

Australia is pushing to reap more value from its mineral wealth and become a leading supplier of battery chemicals. It already supplies around half of the world's lithium and is rich in other minerals critical to the energy transition like rare earths, nickel, manganese and graphite.

The total A$50 million ($34 million) in grants will help develop the next stage of processing for batteries and advanced manufacturing for aerospace, medical, energy and defence applications, Resources Minister Madeleine King said.

"The grants will support Australia's new Critical Minerals Strategy, to be released shortly and which will outline how Australia can capture the significant opportunity of growing its critical minerals processing sector," King said in a statement.

Market participants are keenly awaiting Australia's critical minerals strategy as other jurisdictions such as Canada, the European Union and the US rush to win market share in a processing industry expected to be worth $1 trillion by 2025.

Australia awarded seven companies grants of around A$5 million each and smaller grants to six others.

"While we celebrate the support, our view is the government needs to step up its efforts if it wants Australia to be a cornerstone in metal supply for the energy transition," said analyst Tim Hoff of broker Canaccord.

"It's a good start, but to put it in context China has invested $29 billion in its supply chain for batteries and clean tech."

Grant winners included Australia Energy Storage Solutions which is setting up Australia's first precursor cathode active materials (PCAM) manufacturing plant in Western Australia.

PCAM, in which Australia has identified a competitive edge, is created from mixtures of battery chemicals in the step immediately before battery cell production.

IGO Ltd won a grant to support its plans to produce nickel-cobalt-manganese PCAM, while gold producer Evolution Mining Ltd was given funds for a project to retrieve cobalt from mine waste.

Other grant winners included graphite producers International Graphite Ltd and Ecograf and rare earths developers Northern Minerals and Australian Strategic Minerals.

Reuters | May 18, 2023

UNDERSTANDING MANGANESE ORE MINERALIZATION PATTERN AND CONTROL WITH PROGRESSIVE EXPLORATION, BONAI KEONJHAR BELT, ODISHA

Koushik Mahanta

Abstract

Jone's horseshoe-shaped synclinorium in north Odisha contains discontinuous strata-bound deposits of manganese ore in the Bonai Keonjhar belt. Manganese ore of various grades can be obtained from the Precambrian metasedimentary rocks of this region. The complex nature of the mode of occurrence of these manganese ore bodies confuses the exploration geologist's ability to locate and encounter manganese ore bodies during exploration.

The study area is mainly within Joda West, Tiringpahar, Joribar, and the southern part of the Khondbond leaseholds of Tata Steel Limited in Keonjhar district of Odisha. The study focuses on how to delineate manganese ore bodies based on their mode of occurrence, structural control, and relative position within the stratigraphic sequence.

The manganese ore bodies occur within the lower shale unit, below the Banded Iron Formation (BIF) of the Iron Ore Group (IOG). The ore bodies have a discordant or concordant relationship with the host rock and occurred as stratabound deposits, which are confined by a brecciated chert zone.

The pattern of exploration introduced in the study area is a combination of reverse circulation (RC) drilling followed by core drilling. At first, after demarcating the potential mineralized area through surface geological mapping and structural data analysis, RC drilling is planned in G3 level at a 200-meter interval targeting the anticipated depth of mineralization. If there is a positive intersection of manganese ore within the RC boreholes, then gradually spacing is reduced around the mineralized RC holes to establish extent of mineralization. Core boreholes are planned in G1 level at an interval of 50 meters or less guided by information gathered from RC boreholes to define the three-dimensional geometry of the deposit with a high degree of accuracy.

Keywords: *Folding, Brecciated Chert, Manganese ore*

1.0 INTRODUCTION

A major part of the iron ore production of India and a considerable amount of manganese ore production are obtained from the Precambrian metasedimentary rocks of the Singhbhum region in eastern India by various agencies. Tata Steel Limited is also a key player, mining both iron and manganese ore from the Keonjhar-Bonai belt of the great horseshoe-shaped synclinorium. Manganese ore is an important raw material that holds a key position in the metallurgical industries. Tata Steel Limited is using its captive manganese ore as ferromanganese and silicomanganese in different types of steel.

As per the 2015 NMI database within the country, only 18% of manganese ore falls under the reserve category, whereas the rest, 82%, falls under the category of remaining resources. India has set a target of producing 300 million metric tons of steel by 2030–31, which directly speaks to the high demand for manganese ore in the upcoming years. Hence it is necessary to convert the figures from resource to reserve through detailed exploration. The objective of this study is to understand the manganese mineralization pattern with progressive detail exploration.

2.0 METHODOLOGY

Geological mapping was carried out on a scale of 1:5000 in and around the study areas. The outcrops of the different rock types in the field are studied; the different structural elements present in the rocks are studied, and their orientation is measured with the Brunton compass. Also, borehole lithology is studied to establish a detailed picture of the area. The nature of contact between the lithologies is also studied. The location is plotted on the map using handheld GPS and DGPS. Analysis of the geological data is done in Geo-Orient, AutoCAD Map3D, and Surpac.

Exploration Geologist, Natural Resources Division, Tata Steel Limited

3.0 GEOLOGICAL SETTING AND PREVIOUS WORK

The synformal horseshoe pattern of BIF-bearing greenstone belts of Bonai-Keonjhar is bounded by the arcuate Singhbhum Shear Zone in the north, and the rest three sides by volcanic (Misra et al., 2006) (Fig 1 (b)). This is also known as the Bihar (Jharkhand)-Orissa Iron Ore Craton, assigned to the Iron Ore Group (IOG) of Precambrian age (Banerjee, 1977). This region is characterized by thick piles of volcanic-sedimentary rocks.

The Bonai-Keonjhar belt is well known as a very low-grade supracrustal assemblage of Mesoarchaean Iron Ore Group (*IOG*) (Sarkar and Saha, 1962), or Koira Group (Murthy and Acharya, 1975. Mukhopadhyay et al., 2008). Based on the disposition of a major horizon of Banded Iron Formation (BIF) the general structure of the belt was interpreted to be NNE-SSW trending axis, southerly closing asymmetrical synclinorium with an overturned western limb (Jones, 1934; Dunn, 1940, Dunn and Dey, 1942) and the eastern limb is westerly dipping.

The Singhbhum Granite and the Iron Ore Group are overlain unconformably by the metasediments and metavolcanics of the Singhbhum, Dhanjori, and Kolhan groups during the Paleoproterozoic–Mesoproterozoic timeframes (Saha, 1994; Mazumder, 2005; Misra, 2006; Mukhopadhyay et al., 2006). The IOG rocks in the western Bonai Keonjhar include metabasalts, tuffaceous shales, BIFs, cherts and locally dolomites (Saha,1994).

Structural analysis in the eastern anticline of the 'horseshoe synclinorium' suggests that the banded iron ore formation (BIF) hosting the high-grade iron ore bodies are disposed in three linear NNE–SSW trending belts, each showing an open synclinal geometry. Later cross folding produced development of widespread dome and basin pattern at the sub-horizontal hinge zones of these synclinal fold belts (Ghosh and Mukhopadhyay, 2007).

The structure of the belt is that of a series of NE-SW to NNE- SSW trending, low plunging anticlines and synclines. Resistant litho-units like BIF which host the iron ore deposits are preserved in the synclinal ridges flanked on either side by older sequences along anticlinal valleys (Mohakul and Bhutia, 2015). The topography is further modified by the presence of several faults. The major parts of phyllitic sequence exposed in the Jamda-Koira valley are stratigraphically older to BIF (Mohakul and bhutia, 2015).

Two phases of deformation structures are ubiquitously present (Ghosh and Mukhopadhyay, 2007). Although three generations of deformation have been interpreted by Chaterjee and Mukherjee (1981), the disposition of iron ore bodies resulted by superposition of F3 over F1/F2 folds. Where F1 and F2 folds are co-axial.

Mn-ore bodies of this region are classified into three broad categories such as stratiform, stratabound (-replacement) and lateritic types based on mode of occurrence and their other chemical characteristics (Misra et al., 2006). Mn-ore bands occur in close association with BIF and iron ores. Volcaniclastic shale in large geographic extension encloses these ore bodies.

4.0 STRATIGRAPHIC SUCCESSION

Within the study area, the sequence of the rock types is established through mapping and borehole studies. The stratigraphy proposed by Sarkar and Saha (1983, 1988) and the stratigraphic sequence proposed by Mohakul and Bhutia (2015) are shown in Table 1. During mapping, the author mapped the argillaceous lithology as lower shale. The BIF is exposed in the southern part of Khondbond leasehold and the western part of Joda west leasehold, which are overlying above the lower shale sequence, and dolomite is underlying below the lower shale. The detailed stratigraphy of the area is shown in Table 1. The manganese ore bodies within the Tiringpahar and Joribar leaseholds occur within the lower shale formation and are confined by brecciated chert at the basal part, as shown in Fig. 1(d), whereas at Joda West the manganese ore bodies are confined by brecciated chert both at the top and base parts, as shown in Fig. 1(d).

5.0 LITHOLOGY AND MODE OF OCCURRENCE

Within the study area, the author observed an argillaceous sequence below the BIF. The argillaceous sequence is the lower shale formation, which is mainly grouped by mixed lithologies, i.e., laterite, ferruginous shale, shale, tuffaceous shale, ochre, dense iron ore, manganese ore, manganiferous shale, and brecciated chert. The manganese ore bodies are confined to the lower shale formation of the Iron Ore Group. According to the mode of occurrence, Mn-ore bodies of this region can be classified as stratabound types, having a discordant or concordant relation within the lower shale formation, as shown in Fig. 2. The iron ore bodies are also recorded as a stratabound deposit constrained within the lower shale formation and are mostly associated with manganese ore bodies.

6.0 STRUCTURAL ANALYSIS

Based on the present work, mainly planar structural elements are mapped, like bedding (S0). And the higher-order folds are studied to establish the lower-order folds.

6.1 Bedding and its orientation within study area

- ❖ At the south-western portion of Khondbond area, bedding (S0) is dipping moderately towards the eastern direction. The mean orientation measured in BIF is 341°/24°E (Fig. 3 a) and in shale is 339°/29°E (Fig. 3 b).
- ❖ At the western part of Tiringpahar, bedding (S0) is dipping steeply to gently towards the western direction (mean orientation: :196˚/59˚W, Fig. 3 c).

Table 1: Stratigraphic succession of Singhbhum region and based on observations of the author, stratigraphic succession was mapped in Joda west, Tiringpahar, Joribar, and Khondbond area.

By Sarkar and Saha (1983,1988), Singhbhum region		**By Mohakul and Bhutia (2015), Kiriburu-Joda area**		**Author mapped in Joda west Tiringpahar, Joribar and Khondbond area**
Group/Formation		**Group/Formation**		**Group/Formation**
Newer Dolerite Dykes and Sills		Newer Dolerite Newer Dolerite		
Mayurbhanj Granite				
Gabbro-Anorthosite-Ultramafics				
Kolhan Group		Kolhan Sandstone with polymict conglomerate at base		
…Unconformity……	....	Unconformity…………….....	....	
Jagannathpur Lavas				
Malangtoli Lavas				
Singhbhum Group				
…Unconformity….	.... Unconformity.................	....	....	
Singhbhum Granite (Phase III)				
Epidiorites (Intrusive)				
	Upper Shale with sandstone and Volcanics		Upper Phyllitic Sequence	
	Banded Hematite Jasper with iron ore		BIF (BHJ, BHQ and minor BMQ)	BIF
Iron ore Group (IOG)	Tuffaceous Shale, Tuff and acid volcanics	Iron ore Group (IOG)	Lower Phyllite Sequence: Ferruginous Phyllite,Impure Arenite, Manganiferous Phyllite, Chert and dolomite	Lower Shale Sequence: laterite, ferruginous shale, shale, tuffaceous shale, ochre, dense iron ore, manganese ore, manganiferous shale, Brecciated Chert
	Mafic Lava with tuffs		Basic volcanic (Bonai range volcanic, Brecciated Chert, Dolomite Lotapani volcanic, Jagannathpur volcanic & Nuakot volcanic)	Dolomite
	Sandstone and conglomerate		Quartzite with Quartz pebble conglomerate	
…Unconformity………	....	…Unconformity………..........	....	
Singhbhum Granite (Phase I and II) Older Metamorphic Group & Older Metamorphic tonalite gneiss		Singhbhum and Bonai Granite Older Metamorphic Group & Older Metamorphic tonalite gneiss		

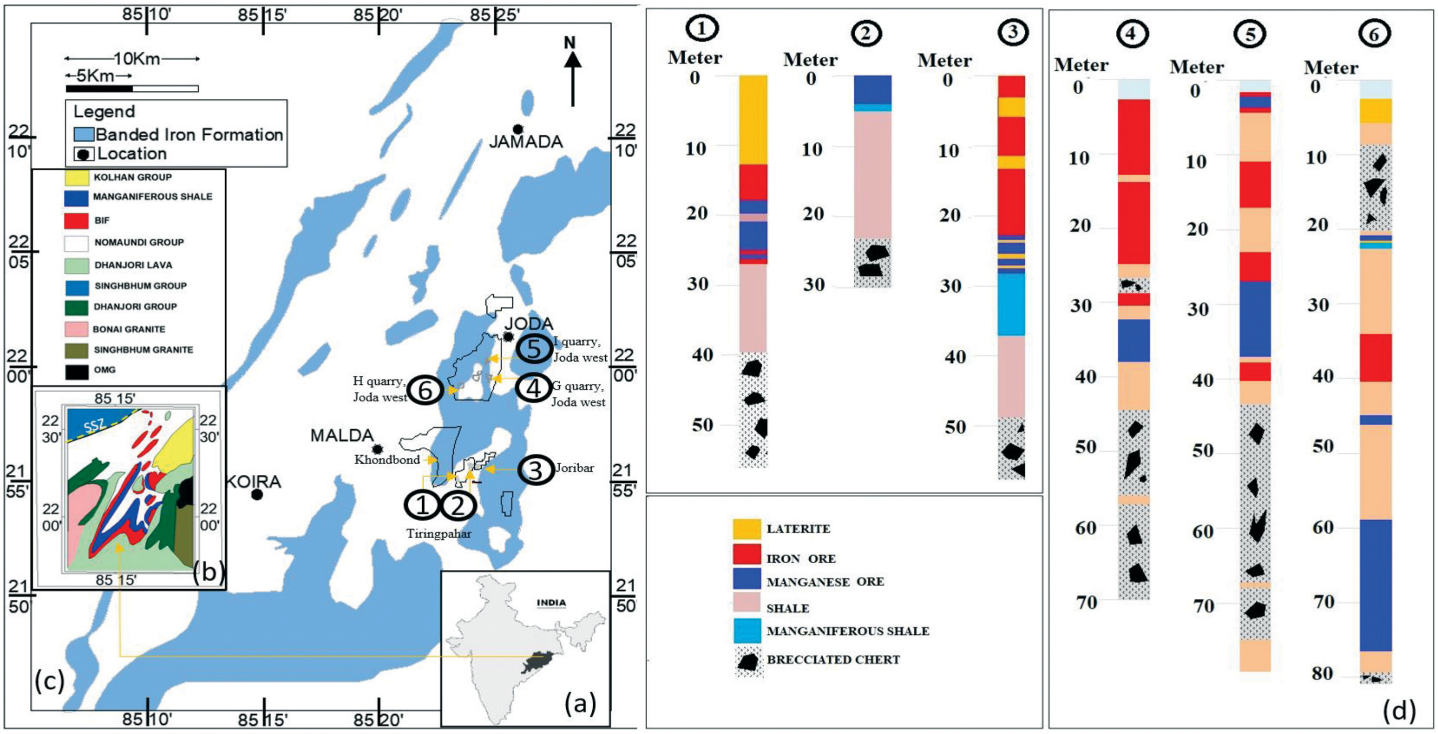


Fig. 1 (a)Map showing location of Bonai-Keonjhar belt. (b) Generalized geological Map of Bonai-Keonjhar belt (modified after Jones, 1934). (c) Map showing the area of study. (d)Logs of borehole lithology in Tiringpahar, Joribar and Joda west leasehold

Fig. 2 Field photographs of stratabound type deposit of manganese ore bodies. (a) Stratabound concordant type of deposit at Gurda pit of Tiringpahar. (b) Stratabound discordant type of deposit at Joda west. (c) (d) Stratabound discordant type of deposit at Tiringpahar.

- At the eastern and northern parts of Tiringpahar, the beds are dipping gently to steeply toward the east. (Mean orientation: 38˚/25˚E, Fig. 3 d.)
- In the southern part of Joribar leasehold, the beds are dipping steeply towards the north (Mean orientation: 291˚/42˚N, Fig. 3 e).
- And at the northern part of Joribar leasehold, the beds are dipping gently towards the south (Mean orientation: 109˚/6˚S, Fig. 3 f).
- Within H quarry of Joda west, the beds are dipping towards the north with a sudden steep dip (Mean orientation: 80˚/63˚N, Fig. 3 g).
- Within I quarry of Joda west, the beds are dipping towards the southeast with a moderate dip (Mean orientation: 54˚/32˚SE, Fig. 3 h).
- Within G quarry of Joda west, the beds are dipping towards the northwest with a moderate dip (Mean orientation: 230˚/41˚NW, Fig. 3 i).

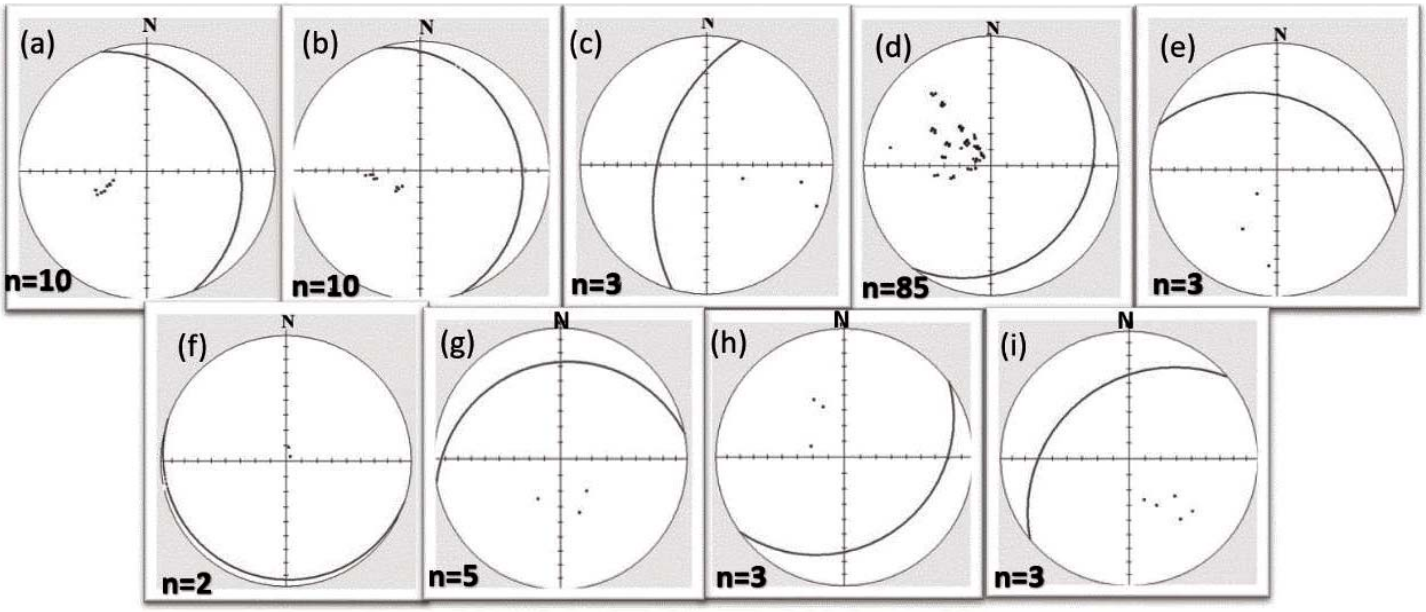


Fig. 3 Equal area projection of the bedding plane (a) Orientation measured on BIF at Khondbond (n=10). (b) Orientation measured on shale at Khondbond (n=10). (c) Orientation measured on the western part of Tiringpahar (n=3). (d) Orientation at the eastern and northern part of Tiringpahar (n=85). (e) Orientation at southern part of Joribar (n=3). (f) Orientation at the northern part of Joribar (n=2). (g) Orientation measured on shale at H quarry of Joda west (n=5). (h) Orientation measured on BIF at I quarry of Joda west (n=3). (i) Orientation measured on shale at H quarry of Joda west (n=3).

6.2 Study of small-scale folds

Within the study area of Tiringpahar and Joribar, the F1 fold has been seen on an outcrop scale, where the plunge of the F1 fold axis was found to be doubly plunging towards the NE and SW directions (31˚→059˚ Fig. 5 c, 35˚→219˚ Fig. 5 a). The orientation of the S1 axial plane is 42˚/75˚SE at Joribar and the central part of Tiringpahar (Fig. 5 d) and at the southern part of Tiringpahar and the southwestern part of Khondbond, it is 04˚/70˚E (Fig. 5 e). The F1 fold is an upright, moderately plunging open fold (Fig. 4 b).

Within the study area of Khondbond, the F2 fold axis has been observed from stereo-net; the plunge direction of F2 is SE (3˚→104˚ Fig. 5 b). The orientation of the S2 axial plane is 109˚/80˚SW (Fig. 5 f). The F2 fold is an upright sub-horizontal open fold (Fig. 4 a).

6.3 Interpreted Large Scale Structure

Within the leaseholds of Khondbond, Tiringpahar, and Joribar, a superposition of two sets of folds has been interpreted by the author as being caused by the interference of two sets of waves, where there exists a superposition of F2 over F1 folds, which resulted in the development of a dome-basin pattern in outcrop scale, as shown in Figs. 6 and 7 (type 1 superposed structures of Ramsay, 1967). The manganese ore bodies are confined by a brecciated chert zone at the basal part and are in concordance with the host lower shale group of rocks.

Whereas within the study area of Joda West, the culmination and depression of the strata are interpreted regionally. The manganese ore bodies are confined within the lower shale and are bound by brecciated chert on both the top and base parts, as shown in Figs. 8 and 9. The ore bodies are having a concordant and discordant relationship with the host rock.

7.0 PATTERN OF EXPLORATION

In this part of India, the pattern of exploration is a combination of reverse circulation (RC) drilling followed by core drilling. Where, after demarcating the potential mineralized area

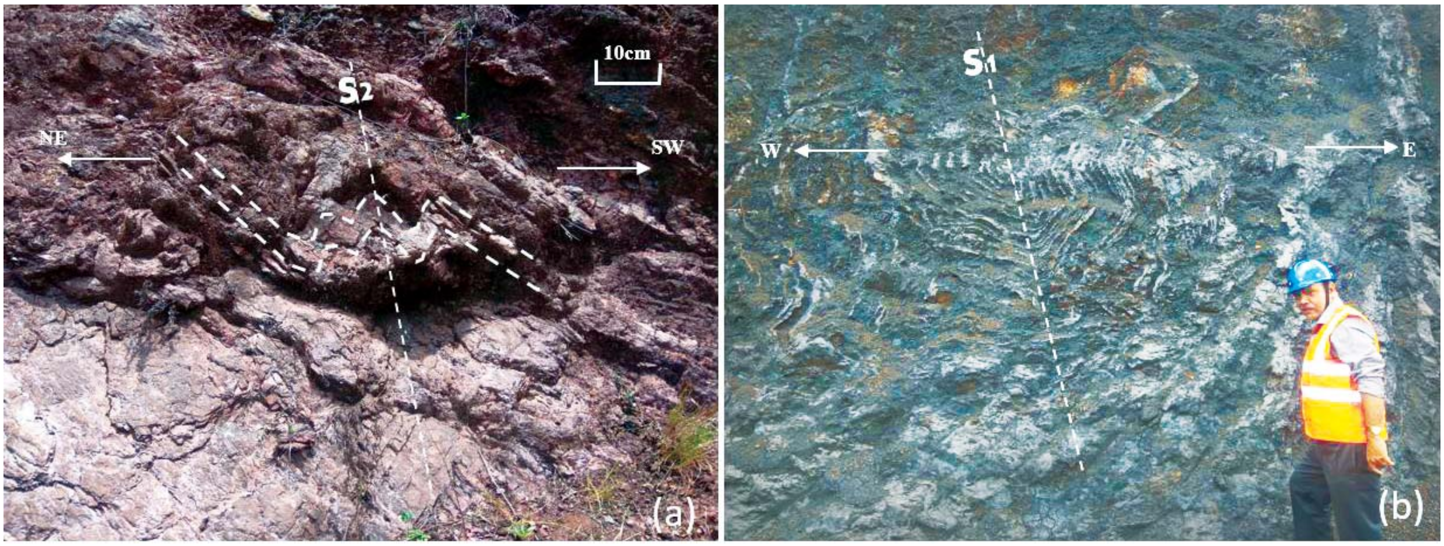


Fig.4 (a) F2 fold observed in Khondbond, axial plane S2 109°/80°SW. (b) F1 fold observed in Joribar, axial plane S1 42°/75°SE

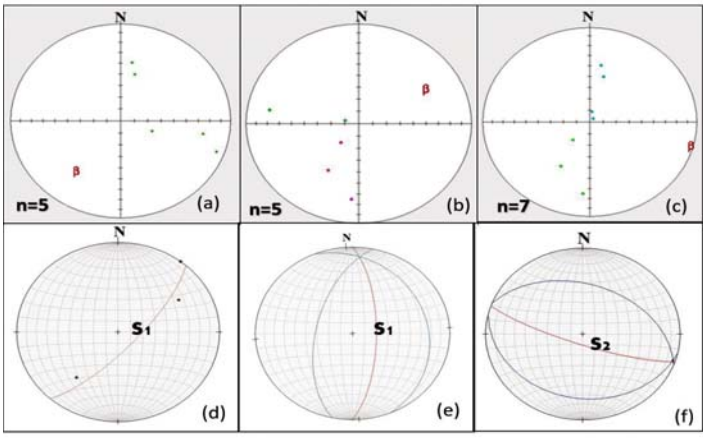


Fig.5 Equal area projection (a) F1 fold axis at southern part of Tiringpahar (n=5). (b F1 fold axis at southern part of Joribar (n=5). (c) F2 fold axis at central part of Tiringpahar (n=7). (d) S1 axial plane measured from the fold axis for Joribar and central part of Tiringpahar. (e) S1 axial plane is measured from the limb's orientation at southern of Tiringpahar and southwestern part of Khondbond. (f) S2 axial plane measured from the limb's orientation at central part of Joribar.

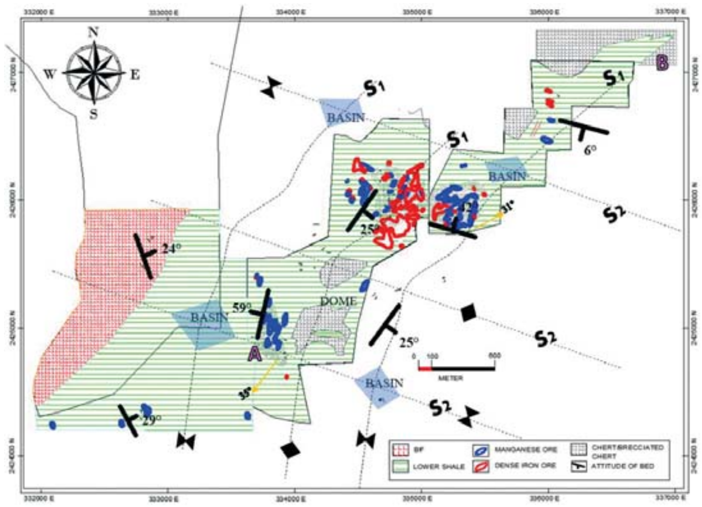


Fig.6 Geological map of Tiringhpahar, Joribar, and Khondbond areas.

through surface geological mapping and structural data analysis, RC drilling is planned at the G3 level of exploration, manganese ore is witnessed to occur as stratabound deposits of irregular habit. Initially, boreholes are planned at grid intersections spaced 200 m apart at G3 level, targeting the anticipated depth of mineralization; if there is a positive intersection of manganese ore, the spacing around the RC hole is reduced to G2 level at 100m apart. Reverse circulation (RC) drilling is deployed in the order of most promising to least promising drill points based on the developed concept of manganese ore mineralization in the area.

Based on the positive mineralization details of the RC boreholes at the G2 level of exploration, the possible shape and grade of the body are delineated. In the next stage, core

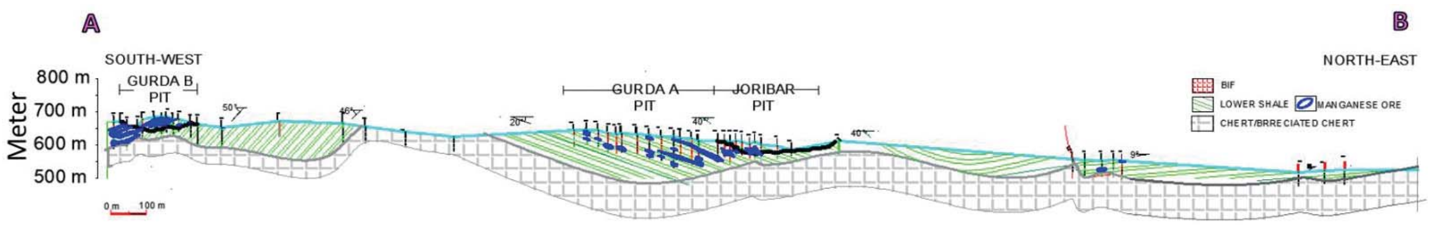


Fig.7 Geological cross section along the line A-B shows a large-scale superimpose folding within the study area.

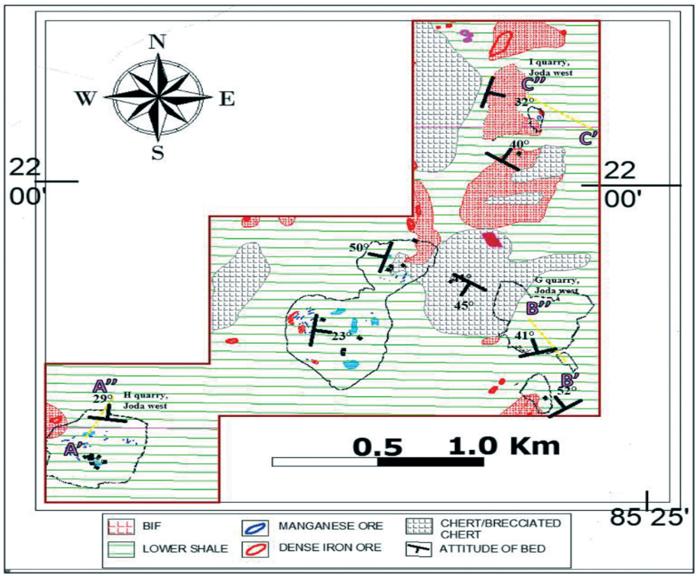


Fig.8 Geological map of Joda west in and around the area of study.

drilling is performed at the G1 level within the mineralized zone at 50m hole spacing or less (25m). Based on the observed mineralization in the core boreholes, the mineralized zone in the explored area is refined and finalized, as shown in Fig. 10.

8.0 CONCLUSION

To delineate the manganese ore bodies, surface geological mapping of the area is very important, so that the potential mineralized zone can be mapped out.

The manganese ore bodies are stratabound deposits within the lower shale formation and are confined by brecciated chert at the basal part of the Tiringpahar and Joribar leaseholds. At Joda West, the manganese ore bodies are confined by brecciated chert both at the top and base.

This method of borehole planning and execution, with initial RC holes in the mineralized area and then followed by core drilling, allows for a higher strike rate during core drilling. This strategy of exploration has helped Tata Steel Limited optimize core drilling requirements, reduce exploration costs, and acquire the required subsurface information for precisely delineating manganese ore bodies during G3, G2 and G1 level of exploration.

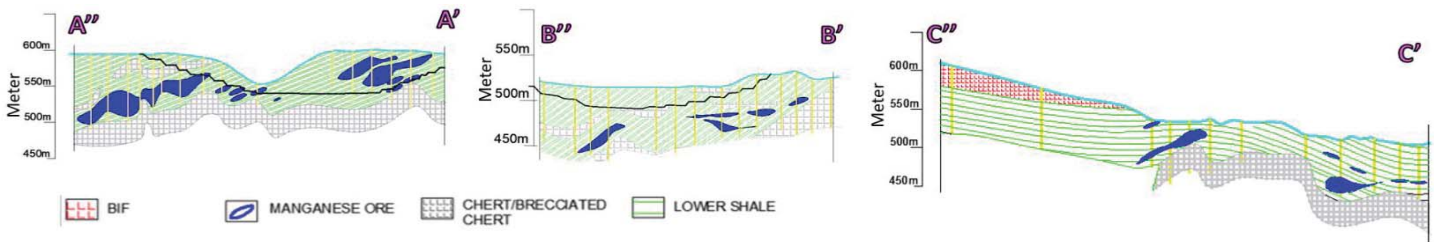


Fig.9 Geological cross section along the line A''-A', B''-B' & C''-C' shows the changes in the orientation of the strata along with the mode of occurrence of the manganese ore bodies.

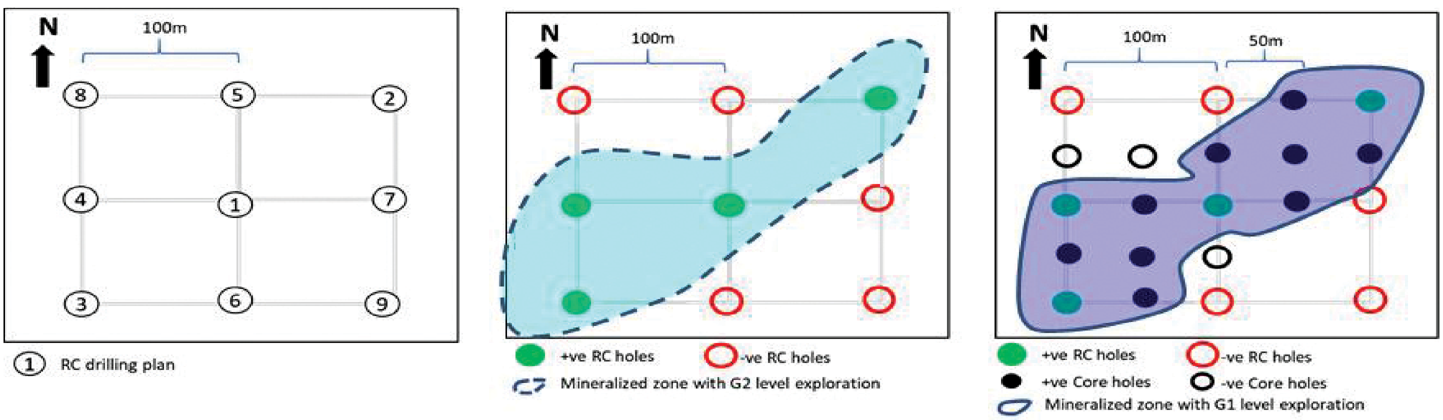


Fig. 10 (a) Demonstrate borehole plan of G2 level exploration for manganese ore which is witnessed to occur as stratabound deposits of irregular habit. Initially, boreholes are planned at grid intersections spaced 100m apart. (b) Based on RC chip logging and chemical analysis results, the possible ore body shape and grade is delineated. (c) In the next stage of detail exploration at G1 level, core drilling is performed within the mineralized zone at 50m hole spacing.

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TRAPPED FLUID INCLUSION IN QUARTZ VEIN INDICATES GOLD MINERALIZATION IS OF MAGMATIC ORIGIN AT CHIGARGUNTA IN KOLAR SCHIST BELT, ANDHRA PRADESH, INDIA

G H Kotnise*

Abstract

The Dharwar Craton (DC) of southern India hosts Archaean orogenic gold in Schist belts within that, the Kolar schist belt hosts the highest percentage of gold (~25 gm/tonne) and is one of the richest gold mineralised area > 800 tonne Au, (Mining Annual Review, Kolar Gold Field), amongst the Archean green stone belt around the world. The southern extension part of the Kolar schist belt i.e. Chigargunta-Kolar schist belt contains promising gold deposit in and around Chigargunta area. This schist belt mainly consists of mafic greenstones comprising metabasalt and metagabbro and pyroxenite, whereas felsic volcanic rocks known as Champion gneiss. Auriferous laminated sheared quartz veins of the Chigargunta-KGF schist belt hosts Gold mineralization and also in the altered Champion gneiss and amphibolite rocks. The mineral assemblage of Chigargunta consists of tourmaline, muscovite, biotite, chlorite, epidote, sericite, calcite and quartz along with sulfide and gold. Sulfides are associated with gold ore predominantly pyrrhotite, pyrite, arsenopyrite, chalcopyrite, ±molybdenite. Native gold is mainly associated with pyrrhotite in the inner and proximal zone of the deposit.

Fluid inclusion microthermometry in auriferous quartz veins and inner proximal zones reveals the existence of a metamorphogenic aqueous–gaseous (H_2O–NaCl-CO_2–CH_4) fluid that underwent phase separation and gave rise to gaseous (CO_2–CH_4) phases from the original fluid and the mode of trapping conditions with the low to moderate salinity (0.66 to 8.64 wt% NaCl equv.) of hydrothermal fluids. The estimated PT range (275 to 430°C and 1.7 to 2.8 Kbar) compare well with the published P–T values of other orogenic gold deposits in general, considerable pressure fluctuation characterize gold mineralization at Chigargunta-Kolar schist belt. The CO_2 density varies from 0.86 to 0.91 g/cm^3 reveals that CO_2 fluids are from deep provenance and large no. pure CH4 inclusions are probably produced by large scale due to regional devolatization. Factors such as fluid phase separation and fluid–rock interaction, along with low near neutral to slightly alkaline H_2O-NaCl-CO_2-CH_4 bearing fluids were collectively responsible for gold precipitation, from an initial low-saline metamorphogenic fluid. Comparison of the Chigargunta-Kolar ore fluids with other lode gold deposits in the Dharwar Craton confirms the low saline aqueous–carbonic composition with metamorphic parentage played the most dominant role in the formation of the Archean lode gold systems. The results envisage that the gold occurrence in Chigargunta-KGF schist belt is of deep-seated magmatic origin and much similar to gold deposits of Kolar Gold Field (KGF).

Keywords: Kolar Schist Belt, epigenetic gold mineralization, microthermometry,

1. INTRODUCTION

Archean schists belts in the Dharwar craton host the orogenic gold mineralizations remain contentious. Similar deposits have formed throughout geologic history and many workers view gold mineralization as an inherent part of ore genesis (Phillips and Powell, 1993; Goldfarb et al., 2004; Groves et al., 2003). Commonly invoked fluid sources include metamorphic volatilisation of highly altered green stones that represent significant reservoirs of CO_2 and H_2O in the mid-crust; or granites that intruded throughout the orogenic/metamorphic cycle (Groves et al., 1988, 2003; Ho et al., 1992; Phillips and Powell, 1993; Elmer et al., 2006). Goldfarb and Groves (2015) have summarized the nature of ore-forming fluids in orogenic gold deposits are metamorphic devolatilization during prograde regional metamorphism of the greenstones and devolatilization of the lower and/or middle crust.

The fluid inclusion study is important from the point of exploration and mine assessment because (i) they confirm

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the depth of extension of gold deposits and (ii) this study can discriminate between auriferous and non-auriferous quartz. (iii) CH_4-bearing inclusions indicate interaction with carbonaceous sediments and have significance in indicating the presence of small pods of high-grade ores within larger lower-grade ore systems (Mishra B., et al., 2008).

The fluid inclusion studies especially in quartz veins found in fracture/shear zones during or later to fluid-rock interactions are important in understanding (i) the nature and sources of the ore fluid and its components and (ii) the physiochemical conditions and mechanisms of ore component, transport, and deposition, particularly in hydrothermal ore processes (Roedder, 1984) and specifically found to be significant in Archean gold deposits. The present study in the Chigargunta-KGF schist belt gold deposit is more suitable as the in situ grade of ore assessed is around 5.0 g/t whereas a huge gold deposit is mined just 30 km north at Kolar Gold Field.

The present study deals with the geological setting of Chigargunta-KGF schist belt and hosts gold mineralisation in quartz veins and also in the altered Champion gneiss and amphibolite rocks. The petrographic studies confirm that gold mineralisation occurs as disseminated and it is associated with pyrrhotite, pyrite and chalcopyrite. The fluid inclusion studies of quartz veins reveals the evaluation of ore forming fluids for understanding of genesis and formation mechanism of gold mineralization in the schist belts of the Dharwar craton.

2. GEOLOGICAL SETTING

The Chigargunta gold deposit is located in the southern part of the Kolar Schist Belt i.e. Chigargunta-Kolar schist belt (CKSB) (Fig.1) located almost in the tri-junction of Andhra Pradesh, Karnataka and Tamil Nadu states in India. The Chigargunta-Kolar schist belt covers around 200 sq km with strike length of about 30 km with a maximum width of 3 km at the centre. The Chigargunta area is situated near to the Kuppam district of Andhra Pradesh and close to the interstate-border area of Andhra Pradesh, Karnataka and Tamil Nadu. In Chigargunta area Champion gneiss and hornblende schist constitute the predominant rock types. The western part of the belt and around Chigargunta is occupied by mafic greenstones comprising metabasalt and metagabbro. The felsic unit (Champion gneiss) which is about 800-1000 m in width occupies the central and eastern half of the south CKSB. It is typically a coarse, inequigranular, strongly foliated rock with large (up to a few cm in diameter) polycrystalline glomeroblast of plagioclase, K-feldspar, biotite, quartz and quartz-feldspar myrmekite, at places, there are embayed grains of quartz and plagioclase. A dolerite dyke, 10 to 30m in width trending N-S to N5^{0}E to S5^{0}W is seen in the central part of the Champion gneiss. A number of pegmatite and quartz veins transect the country rock. The pegmatites are tourmaline bearing and a majority of these trends in a NNE-SSW direction. The champion gneiss is a leucocratic well foliated, coarse to medium grained rock. It is a hybrid rock comprising acid volcanics, metabasic rocks and metasediments. All these components are intimately associated and are extensively modified by hydrothermal activities.

Chigargunta area exhibits local variants of schistose and gneissic types with or without biotite. Muscovite is a common mineral in Champion gneiss apart from rich sericite and biotite alteration. Mafic schist are characterised by a number of parallel shear zones of varying extensions. These are zones of high deformation transecting the country rocks at narrow angles or running parallel to the country rock foliation, postdating the first deformation. These shear zones are ductile to brittle in nature and are mineralised in varying magnitude. In the shear zones the shapes of the equidimensional mineral components and mineral aggregates show significant changes.

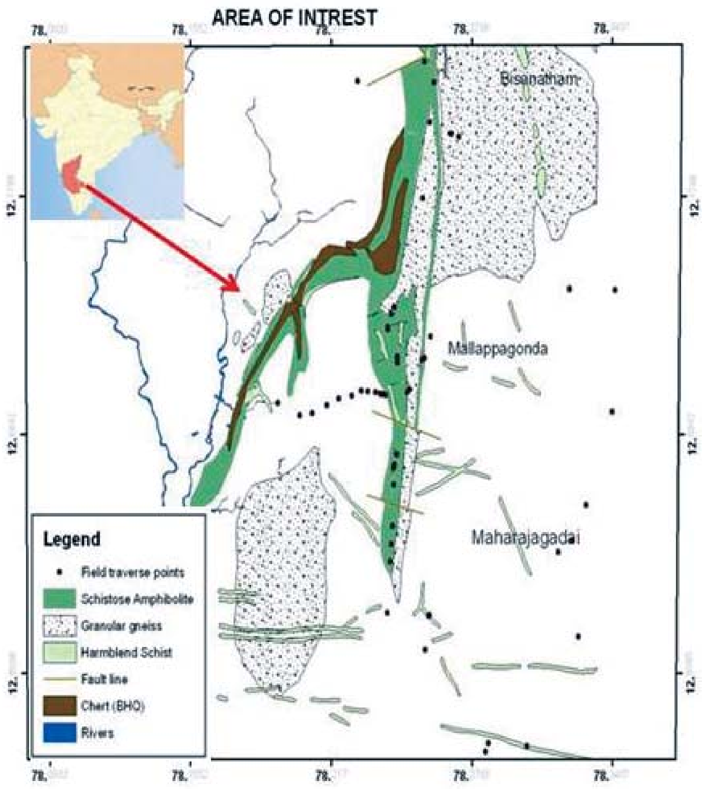


Fig. 1 Geology map of the southern part of Kolar Schist belt (Topo sheet No.57 L/2, Latitude: 12^{0}42'30" to 12^{0}44'00" and Longitude: 78^0 14'30" to 78^0 15' 00").

3. GOLD MINERALISATION

Gold mineralisation in the Chigargunta area is localised along zones of high deformation, which are ductile to brittle in nature and hosts gold in sheared quartz and carbonate veins and are occur over a strike length of 3 km in length with steeply dipping towards both east and west. N-S trending axial planes of the tight isoclinal folds with a mean orientation of 177°/85°W define the key structural control of mineralization. The mineralized shear zones are characterised by a strong mylonitic foliation and profuse hydrothermal alteration and significant changes in grain size and texture are observed in the champion gneiss in proximity to shear zone. The major mineralized lodes occur within the Champion gneiss (east and central), some of the lodes occur within metabasalt, and some at the contact of metabasalt and Champion gneiss (west side).

Fig. 2. Sulphide minerals in quartz vein used for wafer preparation for FIS

Fig. 3. Microphotograph of blebs and irregular grains of sphalerite and chalcopyrite in quartz

Quartz veins occur as veinlets and pods parallel to the shear zone foliation and appear to be liberated from wall rock. Pegmatite and granitic materials are also seen as veins and pods within the mineralized zone. Those granitic veins frequently follow zones with high gold values. Pyrite and pyrrhotite are the dominant sulphides present in the mineralized zones. They occur mainly in disseminated form in the Champion gneiss hosted mineralization. Frequent pyrite dissemination is seen for considerable width in the wall rock of the Champion gneiss. Pyrrhotite is the dominant sulphide along with pyrite. Pyrrhotite sometimes occurs in massive form. Arsenopyrite, chalcopyrite, galena, sphalerite and stibnite are noticed in minor quantities. Galena is always associated with high gold values. Gold occurs in native form within quartz stringers, pods and veins. Native gold has also been found as finely disseminated grains within arsenopyrite. Auriferous zones are confined to discrete ductile shear zones where large scale retrogression of the silicate and quartz-sulphide-gold mineralisation occurred as a result of widespread introduction of hydrous fluid. The spatial association of some acid porphyries within and close to the mineralised shear zones and the hydrothermal alteration of the host rocks point towards an acid magmatic source for the ore fluids.

4. FLUID INCLUSION STUDIES

Fluid inclusion parameters auriferous quartz veins associated with metabasalt and Champion gneiss samples were prepared for doubly polished thin wafers (thickness ~ 0.3 mm). Fluid inclusion microthermometry was conducted with the help of a Linkam MDSG600 Heating and Freezing Stage attached with Olympus BX-50 petrological microscope at National Center of Excellence in Geosciences Research (NCEGR), Geological Survey of India (GSI), Bangalore. The stage can operate in a temperature range of –198 to 600°C. Proper periodic calibration of the stage was done using the pure H_2O-CO_2 synthetic standard inclusions obtained from Linkam. The identification of inclusions was based on genetic and phase types. A large number of fluid inclusions, including primary, pseudo secondary and secondary fluid inclusions were identified using detailed petrographic observations. In accordance with the classification principles and techniques outlined by Roedder (1984), an attempt was made in the light of new experimental studies by Bodnar et al. (1989) on the morphology of fluid inclusions to correlate the different textural features of fluid inclusions. Oriented samples of mineralized quartz veins from trenches/abandoned mines were collected for the detailed studies of nature and composition of trapped fluids which were responsible for mineralization in the area.

The fluid inclusion present within the individual quartz grains occur as isolated, cluster and some are Intragranular and also along the grain boundaries. Based on the phases present in the inclusions are monophase, liquid rich and vapour rich biphase at room temperature. The monophase fluid inclusions are common and are dominantly contain carbonic phase (CO_2) and also a pure methane phase (CH4) are observed. The liquid rich biphase inclusions are abundant and contain vapour of H_2O with liquid H_2O. The intragranular and trans-granular trails are generally observed and contain extremely small and highly distorted monophase and biphase inclusions. These above inclusions are broadly classified into three different types of inclusions. i.e. Type-I monophase carbonic inclusions that occur as primary cluster or isolated inclusions and homogenize into liquid phase (Fig. 4a, b); type-II primary cluster monophase pure methane inclusions (Fig. 4c, d); type-III low saline aqueous biphase inclusions that occur as primary clustered and isolated inclusions and also as intragranular trails (Fig. 4e, f). Type-I inclusions are common in mineralized quartz veins. These inclusions contain only one phase at room temperature. The CO_2 vapour is perfectly circular and spherical and few of the CO_2 vapour bubbles show a dark rim in the periphery at room temperature which is due to the presence of a thin film of liquid CO_2 over vapour CO_2 and is homogenized into the liquid phase. The type-II inclusions are abundant and not so common and these inclusions occur in isolated as well as cluster in type and contain only one phase. The monophase pure methane inclusions are probably produced by the large scale regional devolatilization. The type-III inclusions are comparatively more abundant than any other inclusions and these inclusions occur as isolated and clustered. They are generally small and rounded as well as irregular and contain two phases, liquid (H2O+NaCl) and a vapour bubble H2O (vapour), that is homogenized to liquid upon heating. The proportion of the vapour phase is typically about 10% to 15% by volume. In the shear plane the biphase inclusions are deformed or elongated and orient the strike of the plane of the shear.

Aqso-le and BULK programs were used to calculate the fluid salinity and density respectively whereas, isochores have been constructed with the help of ISOC program, available with the FLUIDS package (Bakker, 2003). Above mentioned salinity and density for type- III inclusions were calculated using the respective equation of state (EOS) of Zhang and Frantz (1987) and Bodnar (1993). EOS of Duschek et al. (1990) and Setzmann and Wagner (1991) were used for type-I inclusions to calculate density respectively. However, isochores were constructed using the EOS of Span and Wagner (1996), Setzmann and Wagner (1991) and Zhang and Frantz (1987) for type-I and type-III inclusions, respectively.

4.1 Microthermometric measurements

Microthermometric measurements of fluid inclusions in mineralized quartz veins from western, central and eastern zones are summarized in Table. 1.

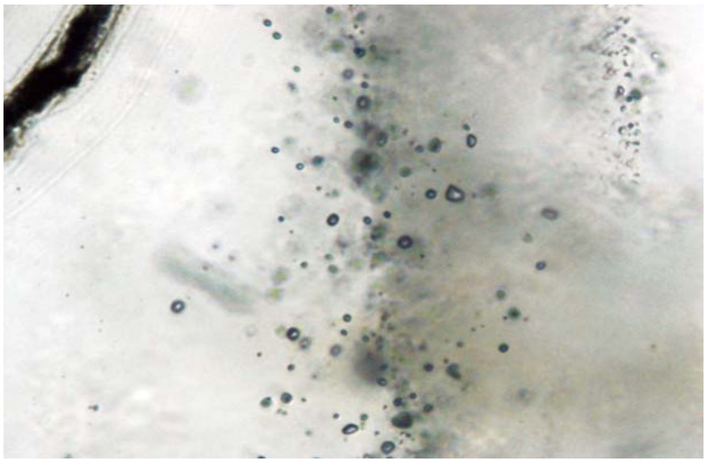
Table: 1.Microthermometric measurement

Samples	Descriptions	Type	Origin	Size (µm)	Tm_{CO2}	Te	Tm_{ice}	Th_{CO2}	Th_{CH4}	Th total	Salinity	Density
Mineralized Quartz veins	Mono phase carbonic inclusions	I	Primary	2-46	-56.6 to -59.2°C	-	-	2.9 to 10.1°C	-	-	-	0.86 to 0.91 g/cc
	Mono phase pure methane inclusions	II	Primary	6 - 30	-	-	-	-	-82.7 to -85.0 °C	-	-	0.18 to 0.22 g/cc
	Aqueous inclusion	III	Primary	2-72	-	-13 to -23°C	-0.4 to -5.6°C	-	-	175 to 272°C	0.66 to 8.64	0.77 to 0.94 g/cc

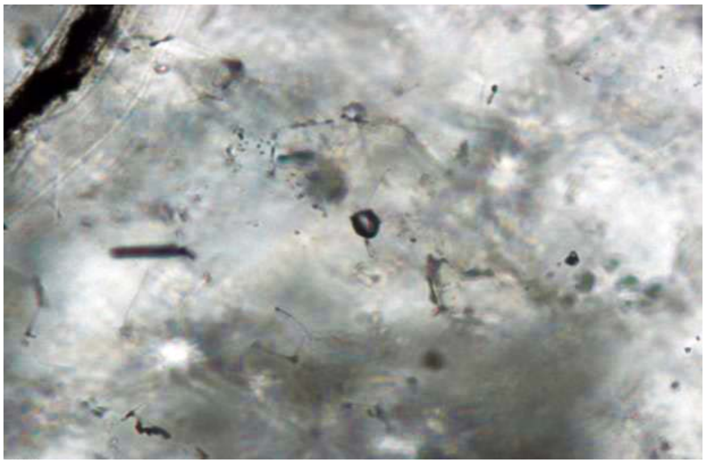
The type-I inclusions are primary carbonic inclusions formed solid CO_2 upon cooling. The solid CO_2 melt ($Tmco_2$) at the temperature between -56.6ºC and -59.9ºC. In most of the inclusions and in few inclusions the melting temperature observed at lower temperature is -57.2 ºC,-58.5ºC, 59.0 ºC, -59.3 ºC and 59.9ºC. This lowering of the melting temperature of CO_2 indicates admixtures of other gases such as N_2 & CH_4 (Brown and Lamb, 1988). The melting temperatures (Tm_{CO2}) are graphically illustrated in histogram Fig. 5a. The temperature of homogenized CO_2 into vapour phase at temperature 2.9 to 19.1 ºC (density varies 0.86 to 0.91 g/cm3) which are graphically plotted in histogram Fig. 5b.

The type-II inclusions are pure methane inclusions are transparent to dark in colour. During the cooling experiments a vapour bubble appears and melting temperature (Tm_{CH4}) was not possible to measure, only the homogenised temperature (Th_{CH4}) was measured and the value ranges from -82.7 to -85.0 ºC, which are graphically plotted in histogram Fig. 5c. The density varies from 0.18 to 0.22 g/cm^3.

The type-III inclusions are aqueous inclusions and are frozen at temperatures mainly between -59ºC to -78ºC. The ranges of homogenization temperature varies from 175ºC to 272ºC and are graphically illustrated in histogram Fig. 5d. During the heating runs the first melting (eutectic) temperature (*Te*) has been observed, ranging from -13ºC to -23ºC with an average of -18.9ºC and suggesting that the major component in aqueous phase is ±KCl with NaCl in the fluid system. The maximum eutectic temperature -23 ºC may indicate the presence of NaCl±KCl and H_2O (Shepherdet al., 1985). The final melting temperature of ice (*T*m, ice) ranges from -0.4 to -5.6ºC (average -2.2ºC) corresponding salinities of 0.66 to 8.64 wt.% NaCl eq., which are graphically illustrated in histogram Fig. 5e The density of aqueous varies from 0.77 to 0.94 g/cm^3.

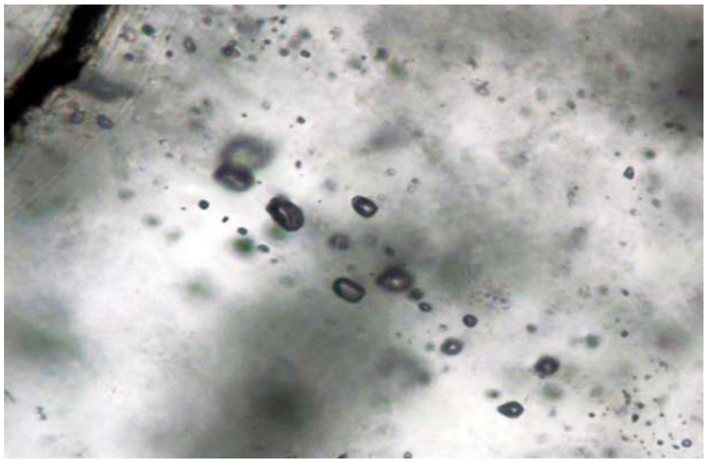


a. Primary monophase Carbonic inclusions.

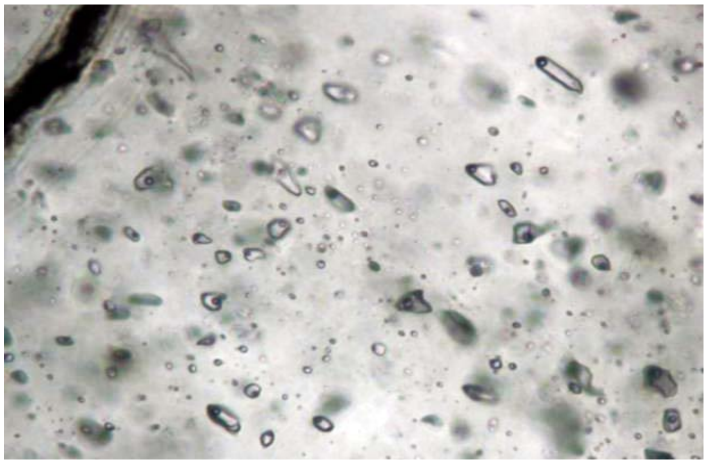


b. Primary monophase carbonic inclusion

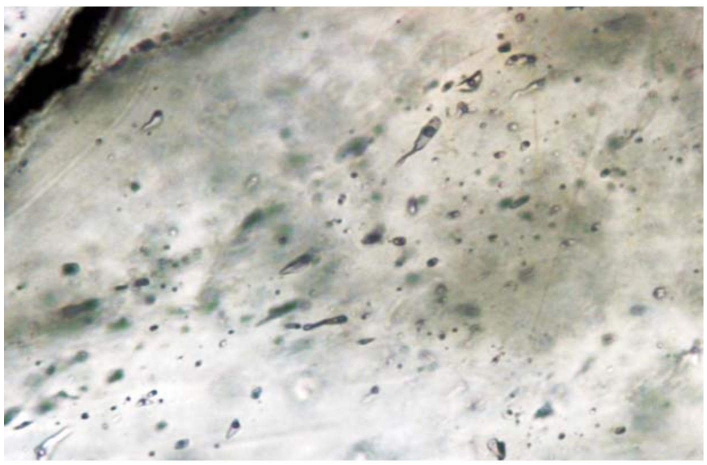
c. Primary monophase methane inclusions



d. Primary monophase methane inclusion



e. Primary aqueous bi-phase inclusion

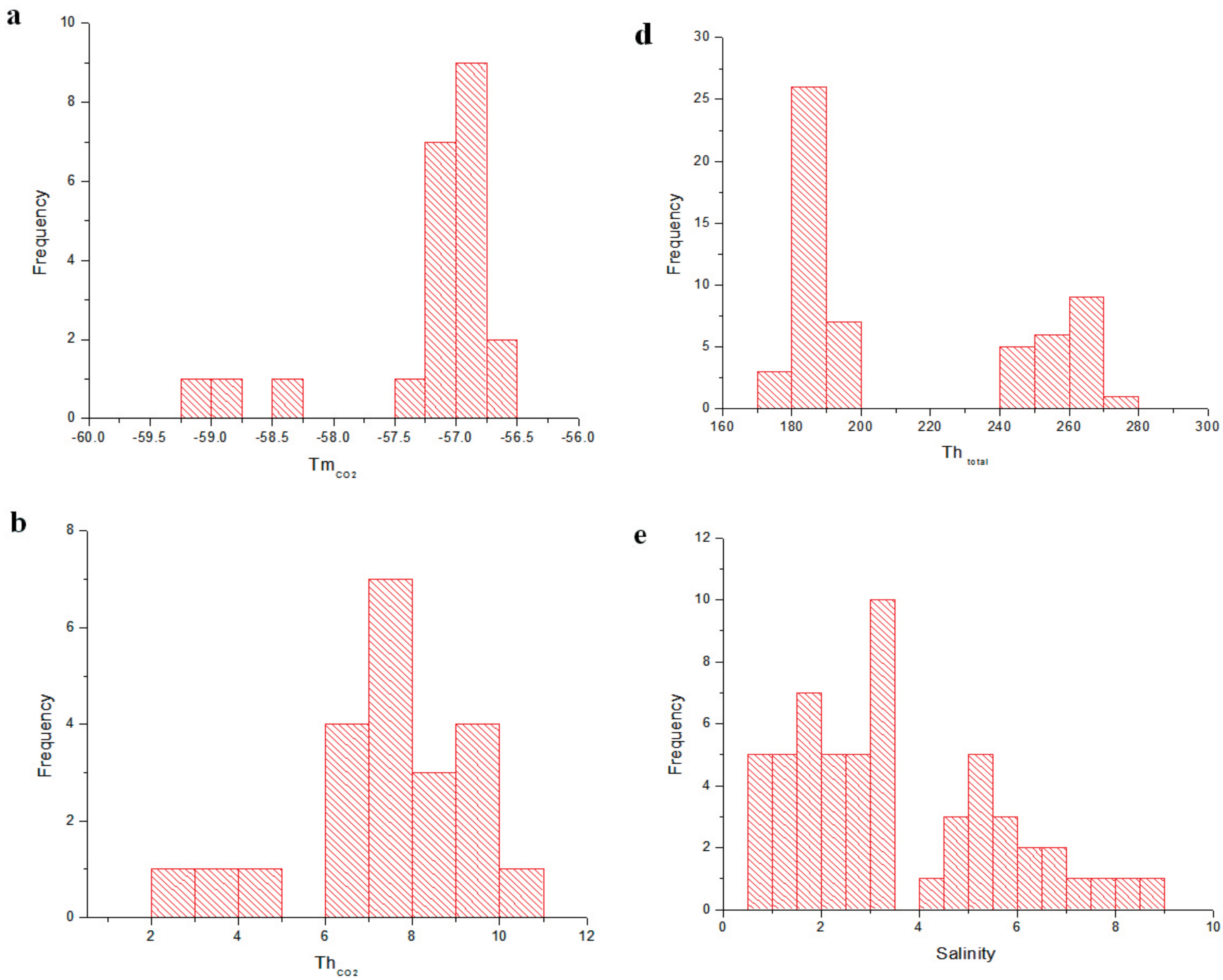


f. Sheared primary aqueous bi-phase inclusion

Fig.4a & b: Monophase Carbonic inclusions (CO_2) Fig. 4 c & d: Monophase Methane inclusions (CH_4) Fig. 4e & f: Aqueous inclusions (H_2O+NaCl)

5. RESULTS AND DISCUSSION

Fluid inclusion studies were carried out in the auriferous zones of Chigargunta-Kolar Schist belt reveals three types of fluid inclusions i.e type-I are monophase carbonic inclusions, type-II are pure methane inclusions and type-III are aqueous inclusions. The total homogenisation temperature (Th_{total}) of the western and central zone varies from 175 to 272°C with corresponding salinity varies from 0.66 to 8.64 wt.% NaCl equivalent. The aqueous inclusions (type-III) are showing higher total homogenisation temperature (Th_{total}) of about



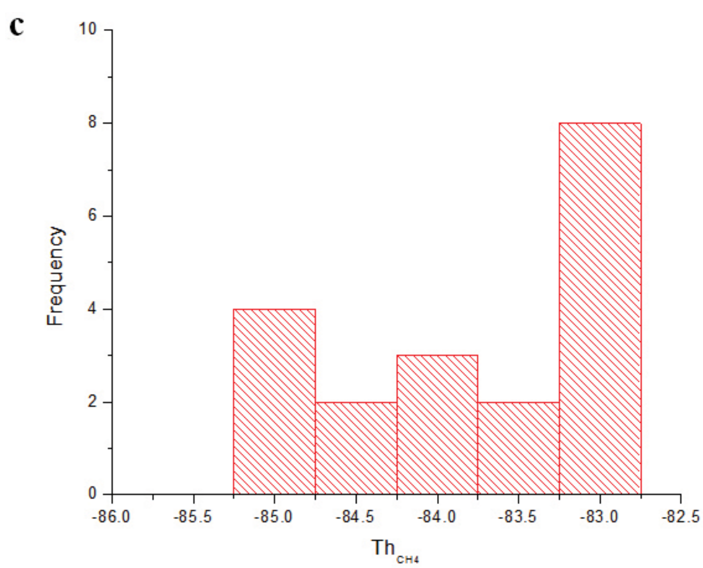


Fig. 5 Histogram plots of fluid inclusion microthermometric data. a) Temperatures of CO_2 melting, (b) homogenization temperatures of CO2 (c) homogenization temperatures of CH4 (d) homogenization of temperature and (e) salinity

maximum 272°C, which represents the exact trapping temperature, because of the occurrence of the phase separation (Roedder, 1984). The CO_2 seems to be an almost universal constituent of the ore fluids depositing gold and it forms major constituents of most fluid inclusions in gold ores from the metamorphic environment. Hutchison (1993) that in such environment gold might have been carried as carbonyal or carbonate complex and that the extraction of CO_2 from the ore fluids by reaction with divalent cations in the wall rock to form carbonates, would result in the precipitation of gold within suitable structural sites (shear zone) through a combination of decreasing temperature and fluid-wall rock interaction, progressive carbonization of wall rocks with decreasing temperature and pressure might lead to fluid immiscibility and separate H2O-rich and CO2 rich phases. These physical separations of two immiscible fluids significantly change the solubility of gold and thus cause precipitation (Groves and Foster, 1993) in the form of quartz veins. The carbonic inclusions shows depression in $Tmco_2$ (ranges from -59.2°C to -56.6°C) due to the presence of traces of CH_4 with CO_2 which is also confirmed by Raman spectroscopy.

The fluid composition was estimated from the eutectic temperatures (T_e) and it ranges from -13°C to -23°C with an average of – 18.9 °C, suggesting that the major component in aqueous phase is ± KCl with NaCl in the fluid system. The maximum of the first ice melting temperature of -23°C may indicate the presence of NaCl ± KCl with H_2O (Shepherd, Rankin and Aldertron, 1985). The final melting temperature of ice ranges from -0.4°C to -5.6°C (average -2.2°C) corresponding with salinities of 0.66 to 8.64 wt.% NaCl equivalent (average 3.54 wt.% NaCl equivalent).

The Salinity vs total homogenisation temperature (Th_{total}) diagram illustrating typical ranges for inclusions from different types (Wilkinson. J. J. 2001), the salinity points fall in the lode Au (gold) deposits (Fig. 6).

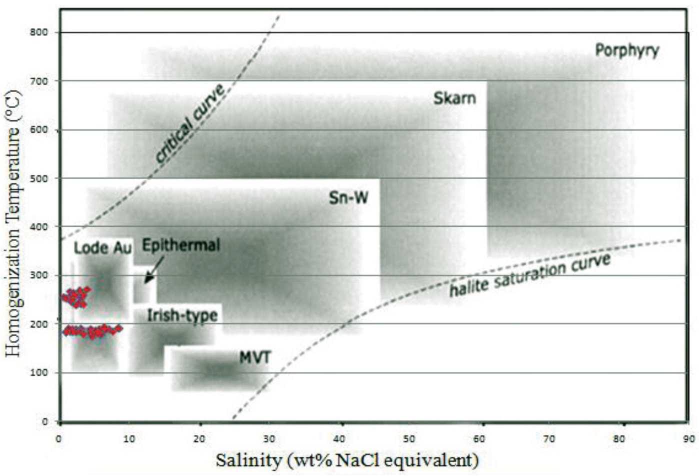


Fig.6 Homogenization temperature vs Salinity diagram illustrating typical ranges for inclusions from differenct deposit types (Wilkinson, 2001)

The P-T condition was estimated using the FLUIDS package (Bakker, 2003). Isochores of Type-I marked with a CO_2 density 0.87 g/cc and 0.91 g/cc and Isochores of Type-III marked with a density 0.83 to 0.93 g/cc. The intersection of isochores to estimate the P-T conditions with corrected pressure. The overlapping regions of the type-I (carbonic inclusions) and type-III (aqueous inclusions), the estimated P-T ranges 275 to 430°C and 1.7 to 2.8 K bars, which almost matches with the other lode gold deposits PT condition of the Archean Dharwar craton (Fig. 7). This P-T range is indicative of gold mineralization and alteration that has taken place at higher temperature range i.e. the upper greenschist to lower amphibolite facies conditions, further relatively high pressure condition was recorded. The deduced gross fluid composition, salinity and P-T condition of the study area are comparable with the published data from other gold and sulphides in the Archean hydrothermal deposits in the granite-greenstone belts shows the temperature ranging from 250 to 400°C and salinity 2 to 6 wt% NaCl equivalent (Brown and Lamb, 1988; Groves, 1993).

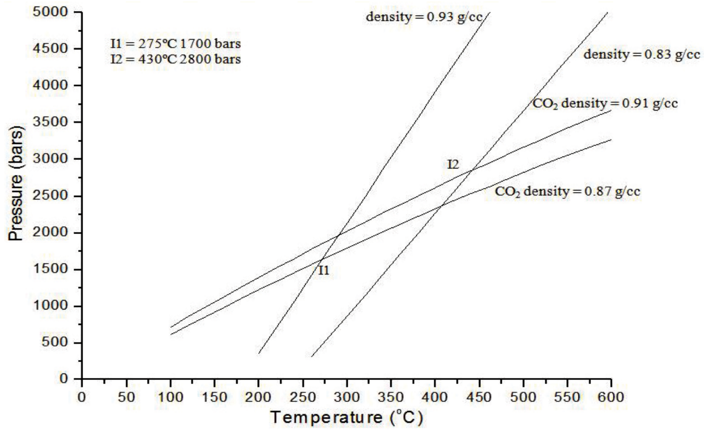


Fig. 7 Isochors of PT condition of the fluid inclusion analysis of densities of each inclusion types.

6.0 CONCLUSION

Kolar Gold Field (KGF) located 30 km north of Chigargunta, the gold mineralization found in brittle-ductile shear zone in mafic/felsic green stones metamorphosed to amphibolites facies and the gold occurs as sulphide poor Au–quartz–carbonate veins (the Champion Lode) and sulfide-rich veins in the Nundydroog mine. While a low saline (~7 wt.% NaCl equiv.) H2O–CO2 fluid precipitated the Champion lode, a low to moderate salinity H2O–NaCl fluids and CO2, characterize the sulfide-rich gold lode. Mineralizing P–T conditions from fluid inclusion studies are 0.7 to 1.8 kbar /205–280 °C (Mishra and Panigrahi, 1999). The bulk of the gold mineralization in the Hutti mine occurs in the laminated quartz veins that constitute the inner quartz–calcite–chlorite zone, and is separated by the proximal biotite–K–feldspar- and rare distal chlorite alteration zones, before grading into the mafic/felsic greenstones that are metamorphosed to amphibolite facies. Low saline H2O–NaCl–CO2–CH4 fluid underwent phase separation at two stages of P–T conditions, i.e., at (i) 1.0–3.5 kbar/350–450 °C, and (ii) 1.0–1.7 kbar/280–320 °C. Gold precipitation in higher P–T stage was due to wall rock sulfidation in proximal biotite alteration zone. The same in the lower P–T domain, as a result of decrease in S content of the aqueous fluid, as a consequence of fluid immiscibility where bulk of the gold formed from a low saline fluid (4–14 wt.% NaCl equiv.) (Pal and Mishra, 2002; Kolb et al., 2005; Mishra and Pal, 2008). Similar to the KGF and Hutti, there were considerable P-T conditions at Chigargunta-Kolar schist belt revealing low to medium salinity (0.66 to 8.64 wt% NaCl equv. with average: 3.4 wt% NaCl equv.), H_2O-NaCl-CO_2-CH_4 fluid which was responsible for gold mineralization.

The presence of methane inclusions when compared to other types of inclusions (carbonic and aqueous inclusions) suggests phase separation from the original fluid and also the fluid trapping conditions. Low salinity (0.66 to 8.64 wt% NaCl equv.) near neutral to slightly alkaline H_2O-NaCl-CO_2-CH_4 fluid with presence of pure methane inclusions further supports the metamorphic origin of the ore-forming fluids. The CO_2 density varies 0.86 to 0.91 g/cm^3, suggesting that the deep-seated hydrothermal fluids carrying gold ions have deposited in the quartz vein along the favourable channels 'ore-shoots' like shears/faults as potential deposits.

7.0 ACKNOWLEDGMENT

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MEAI NEWS

MEAI HEADQUARTERS

MEAI TECH SERIES – April 2023 (MTS–10)

Smart Mining System for Safe & Sustainable Mining by Mr Suryanshu Choudhury, Head Mine Planning, GMDC

Under the banner of the Training, Development & Program Committee of MEAI, with the backing and support of the President, MEAI, Mr. K. Madhusudhana ji, MEAI presented the TENTH Disquisition in the Tech Series for the mining professionals on 28th April 2023 (Friday) at 06:30 pm Online on WebEx platform.

Mr Deepak Vidyarthi, Chairman TDPC extended a warm welcome to the participants as the President, MEAI, Mr K. Madhusudhana in his opening remarks appreciated the continuity of MEAI TECH SERIES, and invited the speaker Mr. Suryanshu Choudhury, Head Mining Planning, GMDC to share his views and experience on Smart Mining System for Safe & Sustainable Mining and wished him grand success in his presentation

Mr. Suryanshu Choudhury made an excellent presentation on Smart Mining. He explained that Smart Mining System is a technological innovation that has enhanced the efficiency of Mining operations while reducing costs without compromising on safety.

He further explained that various technologies connect each other through the internet in a Mining environment. Data gathered at a Smart mine is shared over the cloud and transformed into intelligent inference which can be used to make firm decisions at a site.

By implementing smart technologies, companies can transform complex mining processes into simpler ones. The Global smart mining market has increased exponentially.

With a very interactive session, the Presentation concluded with a Vote of Thanks proposed by Mr T. R. Rajasekar, Consultant to the speaker for the wonderful presentation and for having taken pains for its preparation and to all the participants.

MEAI PROFESSIONAL DEVELOPMENT PROGRAM – III

MPDP-I got started in March 2022 under the guidance of our dynamic president Sri K. Madhusudhana ji who is also one of the faculties.

The journey then continued, and we completed MPDP-II in the month of September 2022.

Now in May 2023 we have successfully completed MPDP-III.

Testimony to the popularity of the program is ever increasing number that touched 41 in May 2023 besides very effective and constructive feedback by the participants.

This would not have been possible without the guidance and cooperation of the members of the Training Development & Program Committee, dedicated & devoted endeavour of the faculties and without the collaboration of sponsoring organizations.

Few glimpses of the MPDP-III program:

Total no of Sessions: 24 – (90 minutes per session)

Faculties: 16

Topics: 22

Participating organizations (14) included #NMDC, #MSPL, #VEDANTA, #TATASTEEL, #JSW, #SMIORE, #ERMGroup, #BKGMining, #DALMIACements, #VESCO, #IMERY, #GeoRocks, #HanumantaRao, #ZEENATH pvt ltd.

At the end of the program the participants were put to test for assessment of their learnings.

Attendance and Assessment were mandatory for participants to be eligible for grant of MPDP Certificates.

We offer our sincere thanks to the Secretary Gen, MEAI and all those who have extended a helping hand in the successful completion of this humble venture.

Deepak Vidyarthi
Chairman, Training, Development & Program Committee of MEAI

Shri. Ajit Kumar Saxena, CMD, MOIL addressing on the occasion of MPDP – III Valedictory function held on 21st May 2023. Shri. Shri. M.M. Abdulla, Director (Production & Planning), MOIL was also present.

GLIMPSES OF MPDP-III

MPDP-III Course

Day 1

05.05.2023

INAUGURAL

Presided Over by
Sri K. Madhusudhana,
President, MEAI

SPEAKERS

- Prof Anup Prasad
- Mr BRV Susheel Kumar
- Mr AR Vijay Singh

MPDP-III Course

Day 2

06.05.2023

SPEAKERS

- Dr More Ramulu
- Prof Bhabesh C Sarkar
- Mr Suresh Nair
- Mr Sabyasachi Nayak

MPDP-III Course

Day 3

12.05.2023

SPEAKER

Mr Deepak Vidyarthi

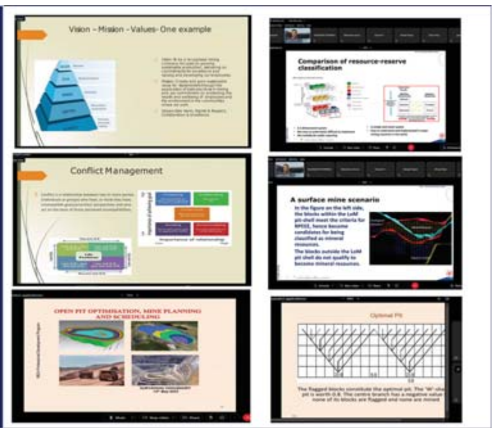
MPDP-III Course

Day 4

13.05.2023

SPEAKERS

- Dr Abani R Samal
- Dr Debabrat Dash
- Mr Suryanshu Chaudhury



MPDP-III Course

Day 5

19.05.2023

SPEAKERS

- Mr AR Vijay Singh
- Dr Ram Chandar Karra

MPDP-III Course

Day 6

20.05.2023

SPEAKERS

- Mr KAV Prasad
- Mr K. Madhusudhana
- Mr T.R. Rajasekhar
- Mr Deepak Vidyarthi

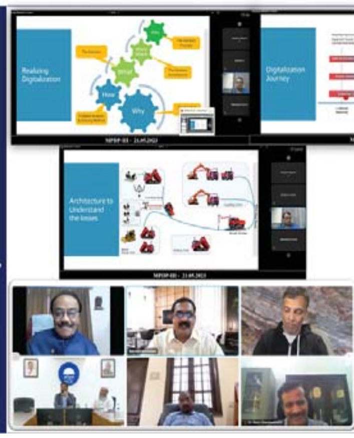
MPDP-III Course

Day 7

21.05.2023

SPEAKER

- Mr Mahesh Kumar
- ASSESSMENT
- VALEDICTORY



VALEDICTORY FUNCTION
Chief Guest
Sri Ajit Kumar Saxena
CMD, MOIL

Presided Over by
Sri K. Madhusudhana
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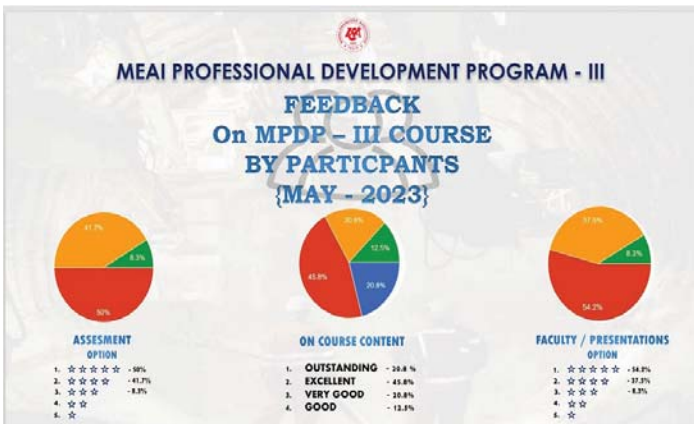

MEJ RIDDLES

Dear Readers of MEJ,

In order to increase the readership of MEJ, which has been felt essential in the interest of our ardent members, the mineral industry professionals as well as the mining sector, the Editorial Board of MEJ has decided to hold a monthly QUIZ. The monthly QUIZ will be designed and printed in MEJ based on the content published in the previous month's MEJ. The MEJ readers will be given five objective questions with multiple choices to choose; and expect them to respond with their correct answer by email to the Editor at **editormejmeai@gmail.com** by 20th of the current month. If more than three members responded with the correct answers, then the three winners will be decided by draw. Each winner will be issued a certificate of merit and a nominal cash prize of Rs 500.

Encourage the EMJ readers to participate in the QUIZ in large numbers and benefit from the enhanced knowledge by reading the Journal from the first to last page.

Questions based on MEJ May 2023 issue

1. Who made a technical presentation on applications of Surpac in MTS-9, organized by MEAI?

(a) Mr Pramod Sarangi (b) Dr Abani R Samal

(c) Mr Suryanshu Chaudhury (d) Mr Deepak Vidyarthi

2. Who was the presenter on Reporting of Diamonds and other Gemstones in the IMIC Professional Development Program held at MEAI HQs in April 2023?

(a) Dr AK Sarangi (b) Mr Manish Tomar

(c) Dr TM Babu (d) Dr A Santharam

3. What is the production plan of IREL to produce Rare Earths bearing ore by end-2032?

(a) 40 Million tonnes (b) 50 Million tonnes

(c) 30 Million tonnes (d) 60 Million tonnes

4. What percentage of total workforce in India have undergone formal skill training?

(a) 5% (b) 10%

(c) 15% (d) 20%

5. Which professional body in India was recognized as "Professional Organisation (PO)" by CRIRSCO on August 1, 2019?

(a) Geological Society of India (b) FIMI

(c) ASSOCHAM (d) MEAI

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To receive the cash prize of Rs 500, the winners may please contact the Secretary General, MEAI on email at **meai1957@gmail.com** or Mob. 9177045204.

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25-27 Aug 2023: **International Seminar on Vision – Mining 2047**. Location: Ahmedabad. For details, contact Email - meaiahmedabad@gmail.com

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6-9 Nov 2023: **International Mining, Equipment & Minerals Exhibition (IME 2023)**. Eco Park, Rajarhat, Kolkata, India. Organised by The Mining, Geological & Metallurgical Institute of India (MGMI). Contact Email ID: miningexpo@tafcon.in

ABROAD

4-5 Mar 2023: **International Conference on Mining and Refining of Metals ICMRM**. Rome, Italy. Website URL: https://waset.org/mining-and-refining-of-metals-conference-in-march-2023-in-rome

4-5 Mar 2023: **International Conference on Mining Intelligence (ICMI 2023)**. Rio de Janeiro, Brazil. Website URL: https://waset.org/mining-intelligence-conference-in-march-2023-in-rio-de-janeiro; Contact URL: https://waset.org

5-8 Mar 2023: **PDAC 2023.** The annual PDAC 2023 Convention – the world's premier mineral exploration and mining convention. Metro Toronto Convention Centre, 222 Bremner Blvd., Toronto, Ontario, M5V 3M9, Canada

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25 - 28 Oct 2023: **China Coal & Mining Expo 2023**. China's 20th International Technology Exchange & Equipment Exhibition on coal and mining is the largest international coal and mining exhibition in Asia. New China International Exhibition Center (NCIEC), 88 Yuxiang Road, Tianzhu Airport Industrial Zone, Shun Yi District, Beijing, China

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