

# HYDRO-GEO-CHEMICAL STUDIES FOR PROMINENT KARSTIC FEATURES OF SONADIH LIME-STONE MINING AREA IN DISTRICT BALODA BAZAR [CG]

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## Abstract

Limestone deposit of Baloda Bazaar has been well known basic raw material for Cement Industry of Chhattisgarh. The stromatolic limestone occurrence as surface outcrop with negligible soil cover has been great attraction for Open Cast mining activity in the area since the past thirty years and likely to be continued by several private organizations.

The stromatolic limestone of the area has been associated with karstification process-geologically. It has hydro-geological significance for promising groundwater occurrence. The karstification in the area has been responsible for the presence of eight prominent karstic features namely: Spring, Padi-plain, Terra rossa, Solution cavities, Sink-hole, Paleo-karst, Paleo-drainage and Disappearing stream. All the karstic features have been identified and documented in the area through field observation in conjunction with Geophysical and Remote Sensing tools. The evolution of these karstic features is governed by local litho-logy, geo-morphology, hydrology and hydro-geology.

The formation of karstic features depends upon inter-relationship among rock-water-chemistry. The chemical reaction cum inter-relationship has been interpreted to ascertain the mechanism and process of their formation. Nineteen groundwater sampling have been collected through different sources in the area for their analysis carried out through Piper diagram. It has been deciphered their hydro-geochemical aspect with the explanation for formation of karstic features in Sonadih limestone mining area.

## Introduction

Sonadih limestone mining area has two main types of limestone namely: Stromatolic and Dolomitic. The stromatolic limestone has been derived through karstification process-geologically and governed by litho-logy, geomorphology, hydrology, structural geology and vegetation under the influence of ground-water with widely distribution in the area. The Dolomitic limestone has been scattered as isolated patches, devoid of karstification with lesser amount in the area.

The karstification has been responsible for presence of prominent karstic features like; Spring, Padi-plain, Terra rossa, Solution cavities, Sinkhole, Paleo-karst, Paleo-drainage and disappearing stream. The formation of karstic features depends upon local geo-chemistry of rock-water interaction. The hydro-geochemical interpretation with relation to field observation of karstic features has provided convened [logical] explanation for their process of formation, mechanism in Sonadih limestone mining area.

## Area of Study

Sonadih limestone mining area has about 4.5 Sq. Km geographic area with the geographic coordinates: Latitude N 21°43' 31" to 21° 44' 25 " and Longitude E 82 ° 11' 17" to E 82° 12' 36" in district Baloda Bazar [CG]. Hydro-logically, it has been covered by two watersheds namely: Jamunia nadi and Khorsi nalla in eastern and western direction respectively along southern flank of perennial Sheonath river. It is approachable by road through Raipur-Belha Road, State Highway No.130 B and rail link through Bhatapara Railway Station on SECR. The location map for the area of study is illustrated as Fig. 1.

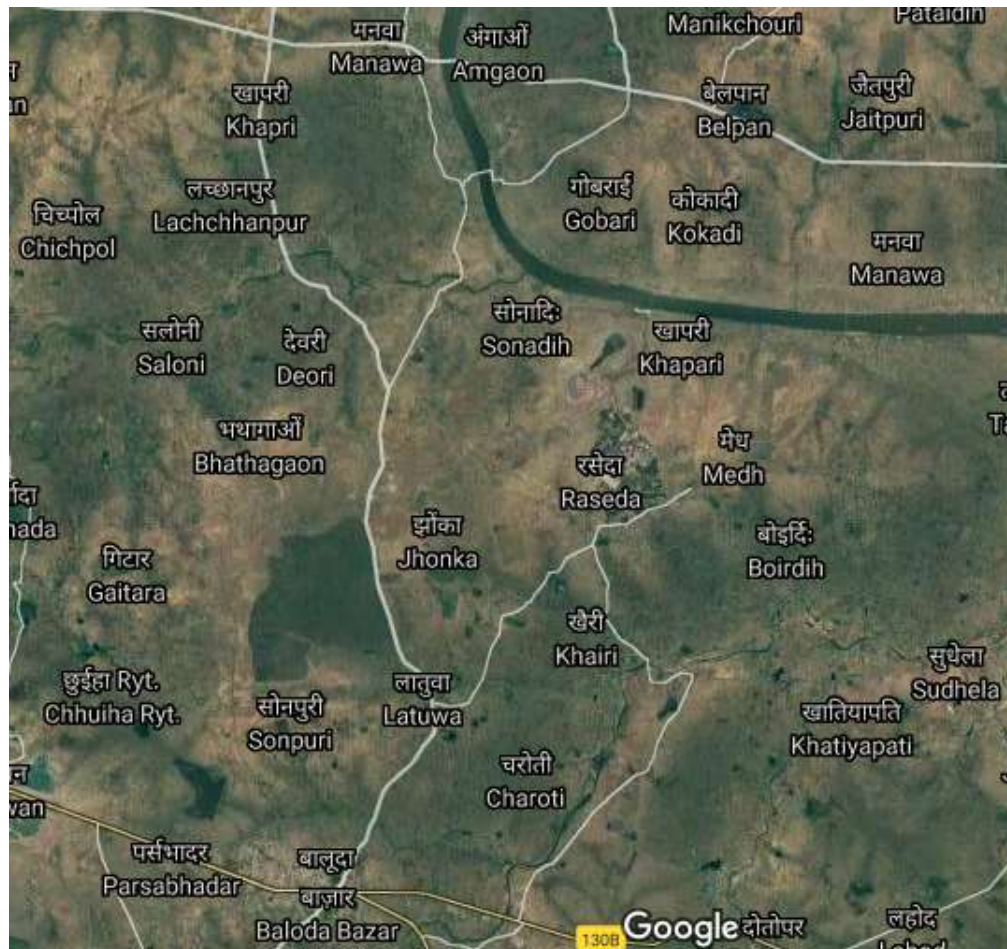


Fig. 1 The location map for the area of study

## Evolved methodology & Objectives

The evolved methodology has two approaches namely: Theoretical and Field Investigation. Theoretical approach is based upon relevant literature review and discussion with Emeritus Professor Dr. B C Raymahashaya, of IIT Kanpur. The field observation is based upon identification cum documentation of karstic features with their validation to required necessary Geophysical and Remote Sensing tools and logical in-puts to theoretical aspects cum Hydro-geochemical interpretation of collected groundwater samples.

The desired objectives of the study are as follows:

- Identification of karst chemistry through available major litho-facial variation.
- Hydro-geochemical interpretation of collected ground-water data for prominent karstic features.
- Documentation cum recognition of prominent karstic features along with their formation mechanism cum process, based upon geo-chemical affinity.

## Result & Discussion

The adequate understanding of karstification process depends upon local Geology, Lithology, Geo-morphology, Hydrology, Hydro-geology, and Vegetation characteristics, besides Mining and allied Processing. [2].

Geologically, the area belongs to Chandi limestone formation of Raipur group of Chhattisgarh basin, typical Proterozoic sedimentary terrain. It had been formed during Precambrian period, about 3000 million years ago.

Lithologically, the Chandi limestone formation had been dominated with three carbonate-shale cyclothem. Each unit of cyclothem is characterized by three litho-facies namely: Calcium Bicarbonate, Calcium-magnesium Bicarbonate and Calcium-sulfate Bicarbonate respectively.

Geo-morphologically, the area belongs to two types of plain with occasional small undulations, namely: Flood plain & Pedi-plain. The Flood plain is associated with perennial river regime. The Pedi-plain is associated with limestone terrain.

Hydro-logically, the area has two distinct water-sheds namely: Jamunia nadi in western portion and Khorsi nalla in eastern portion. The intermittent nalla is in the middle portion of mining lease area. The surface drainage is of dendritic pattern, has been super-imposed on both prevailing watershed characteristic with flow direction towards north meeting to Sheonath river. The average annual rainfall is 1350-1450 mm.

Hydro-geologically, the area has two aquifer dispositions namely: promising and poor. The promising aquifer belongs to stromatolitic limestone. The poor aquifer belongs to dolomitic limestone. The hydraulic gradient has range 2.5 to 4.5 m/Km from higher elevation to the flood plain. The ground-water level fluctuation for stromatolitic limestone has range 1.1 to 12.5 m bgl in the pre-monsoon period. Three groundwater bearing zones occur namely: Shallow [less than 5 m bgl], Moderate [6-10 m bgl] and deeper [more than 10 m bgl]. The ground-water fluctuation for post-monsoon period has range 2-5 m bgl.

The vegetation characteristic of the area has two types depending with respect to H F L of Sheonath river. The water loving vegetation comprising with seasonal fruits and vegetables occurs within H F L zone during pre-monsoon period. The lush green vegetation including bade jhar ka jungle occurs in limestone terrain above H F L zone along slightly depression area in all seasons.

The ongoing mining activity during the past thirty years has developed variety of LU-LC [Land-Use, Land Cover] on the ground surface. It has also developed within the sub-surface through blasting and excavation with enhancing unknown dimension and orientation of fractures with disturbing the original porosity and hydraulic conductivity of limestone, new sink holes formation.

The processing activity in the form of functioning local Cement plant has disturbed the configuration of intermittent nalla and quality of water through industrial effluent discharge. The enhanced toxicities level among water quality of Cement plant globally observed at several places.

### ➤ Identification of karst chemistry through available major litho-facial variation

The karst chemistry has been related basically with each distinct litho-face within limestone formation. It has been influenced by varied ion concentration of Bicarbonate in weak Carbolic acid [H CO<sub>3</sub>]-present as karst-water. The rock-water chemistry for each litho-face has been summarized as follows [5]:

[1] Calcium-Bicarbonate litho-face has origin from bedrock dissolution, through all kinds of weathering.

[2] Calcium-magnesium-Bicarbonate litho-face has origin from weak carbolic acid with more concentration of hardness, on account of higher solubility product of magnesium.



[3] Calcium-magnesium-sulfate-Bicarbonate litho-face has origin from processing activity [in the form of local Cement plant], releasing untreated industrial effluent with higher concentration of heavy metals along intermittent nalla.

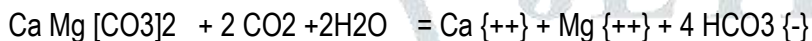
➤ Hydro-geochemical interpretation of collected ground-water data for prominent karstic features

The ground-water sampling has been collected through nineteen different sources in the mining lease area. It has included both types of aquifer, dug-wells, bore-wells, sink-hole, spring, sump, pumped out mine-water, accumulated water adjoining mining rejects. The various hydro-geological parameters for determination of ground-water quality have been summarized as Table1 [3]. The ground-water quality data has been plotted on Piper diagram for standard hydro-geochemical interpretation [6]. The inferences for each litho-face through hydro-geochemical interpretation have been summarized as follows:

[1] Calcium-Bicarbonate litho-face favors higher kinetic energy on account of combined dissolution and precipitation. It may be explained through following chemical reaction [1]:



[2] Calcium-magnesium-Bicarbonate litho-face favors under-saturation condition on account of slow rate magnesium dissolution and may be explained through following chemical reaction:



[3] Calcium-magnesium-sulfate-Bicarbonate litho-face release more water favoring weak ionization [dilution] with zero Carbon Dioxide pressure, sometimes less than atmospheric pressure. It may be explained through following chemical reaction [1]:



The exact behavior of hydro-geochemical aspects of karst features may be studied through superimposing of hydro-geological [qualitative] parameters hydrograph over chemograph with field validation and EC data [4].

S N	Hydro-geological Parameters [mg/l]	Limestone Litho-face [Max-Min range]	Dolomite Litho-face [Max-Min range]
1	pH	7.9-8.4	7.7 -8.1
2	Total Hardness	133-660	224-272
3	Total Dissolved Solid	202-668	236-484
4	Calcium	30-140	35-75
5	Sodium	6-120	9-20
6	Magnesium	21-63	18-45
7	Bicarbonate	138-453	232-427
8	Chloride	16-184	16-48
9	Sulfate	0-23	Nil

Table 1: Groundwater quality data for major hydro-geological parameters of both aquifers in Sonadih limestone mining area.

44 Exploratory bore-holes have been drilled in mining area during 2018 -2019 period

- Documentation cum recognition of prominent karstic features along with their formation mechanism cum process, based upon geo-chemical affinity

Eight prominent karstic features in the area of study have been recognized through field observation in conjunction with-digital analysis of Satellite data [Remote Sensing] and resistivity investigation [Geophysical] tools. The karstic features have been grouped into two categories on the basis of their origin namely: Fluvial & True karst. The mechanism cum formation process of these karstic features on the basis of hydro-geo-chemical interpretation has been summarized in Table: 2.

S N	Karstic Feature	Origin	Recognizing Criteria	Mechanism of Formation	Remarks
1	Spring	Fluvial	Field Observation	Intermixing of surface water & Ground-water along litho-logical contact	Near Shivrath river
2	Pedi-plain	Fluvial	Field Observation	Prominent fluvial action above base level of river	Mining lease area
3	Terra Rossa	True karst	Field Observation	Large climatic variation over geologic period	Physical weathering
4	Solution cavities	True karst	Field Observation cum Geophysical tool	Intermixing of rain-water & Ground-water by dissolution cum precipitation	Geochemical weathering
5	Paleo-karst	True karst	Field Observation cum Remote Sensing tool	Slow rate dissolution with prolonged saturation	Khorsi nalla
6	Paleo-drainage	True karst	Field Observation cum Remote Sensing tool [Band Ratio 4/2]	Conduced ground-water under compressed CO <sub>2</sub> with maximum saturation	Jamunia nadi
7	Dis-appearing stream	True karst	Field Observation	Intermixing of surface water with shallow ground-water along joints	Cement Plant
8	Sink-hole	True karst	Field Observation cum Remote Sensing tool	Low CO <sub>2</sub> pressure within un-saturated zone, influenced by surface water	Mine pit, Mine rejects

Table: 2 Documentation cum recognition of karstic features with their origin and mechanism of formation

The geochemical affinity in the formation process of each karstic feature has been summarized as follows [7]:

- Spring – The formation of spring has been governed by litho-logical variation, ground-water discharge through underground conduit as well as intermixing with surface water in regime of perennial river. It has been used to accelerate by small undulation on ground surface as well as vegetation cover.
- Pedi-plain – It is depositional feature, influenced with fluvial activity. It has been formed through hydro-geomorphological process, with devoid of any soil cover.
- Terra Rossa - It is on account of physical weathering to the underlying limestone-dolomite bed rock. It is reflected by large amount of climatic fluctuation during past geological period. It has reddish-brown color soil with residual nature.
- Solution cavities – It is formed basically through varied nature of kinetic energy, released by geochemical weathering on account of dissolution cum precipitation of carbonate soaked sediments in sedimentary terrain. It leads to a kind of interaction among weak carbolic acid present in rainwater, which erodes downward through dissolution activity with chemical reaction to ground-water for developing hallow cavity.
- Paleo-karst – It is subdued variety of karst feature formed in dolomite rich limestone terrain. It is on account of slow rate dissolution with karst-water at subsurface under prolonged saturation range. It is sub-surface phenomena and deciphered through Remote Sensing tool.
- Paleo-drainage – It is formed due to delayed interaction in between available ground-water in conduit system, developed due to varied hydraulic conductivity [horizontal and vertical variation], involving maximum degree of saturation under compressed carbon dioxide pressure. It is illustrated as **Fig. 2 [ Band Ratio 4/2]**
- Dis-appearing stream – It is governed by third litho-face namely-Calcium-magnesium-sulfate –Bicarbonate with resurgence in nature. The water dis-appears along rectangular open joint pattern at base rock through downward circulation in shallow saturation zone and interacting with ground-water of unconfined aquifer [8]. The water appears in the path of stream/intermittent nalla during monsoon period due to mine water in association with it's base flow, without ascertaining surface headwater. It is further influenced by dumping of mine rejects as well as industrial effluent of Cement plant.
- Sink-hole - It is formed due to percolation of rain-water along fracture induced porosity due to ongoing mining activity, under vadose zone. It causes rapid to lower/reduce carbon dioxide pressure, even less than atmospheric pressure. It has enclosed depression with cylindrical shape, due to presence of impermeable shale bed at the base. It is illustrated as **Fig.3.**

The accurate calculation of solubility product of calcium, magnesium and bicarbonate depends upon saturation rate, kinetic energy released in geochemical reaction, carbon dioxide pressure during formation process of karstic features and may be best carried out through PHREEQC –software program, available with USGS.



FIG.2 PALEO-DRAINAGE AS OBSERVED THROUGH BAND RATIO 4/2



FIG.3 SINK-HOLES AS OBSERVED THROUGH GOGGLE

### Summary & Recommendation

Eight prominent karstic features for the area of study have been identified and documented. The different mode of formation process and mechanism for karstic features has been explained through hydro-geochemical analysis on the basis of the quality of ground-water data. The on-going mechanized mining activity in the area has influence on local aquifer dispositions as well as karstic features.



The recommendation for further research in the area includes a technical program of Geo-physical, Geochemical, Remote Sensing and Hydro-geological interpretation cum analysis of karst system with establishment of closed water network monitoring [quality and quantity in terms of mine-water pumping rate & ground-water level fluctuation] in 10 km radius of mine nucleus as per mandatory requirement of Environmental Impact Assessment as well as optimization of industrial growth with conservation of renewable resource of potable water.

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