

A note on gold in southern Rajasthan-A conceptual model

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ABSTRACT

In Rajasthan, the metasedimentary and metavolcanic of the Lower Aravallies has been represented by earlier workers as an abortive Proterozoic greenstone belt. The occurrence of gold, therefore, has been postulated in the Paleoproterozoic belt extending from Nathdwara in the North to Jhabua in Madhya Pradesh in the South. A tectonic lineament, suggested by workers and supported by Landsat imagery, represents a zone of discontinuity of tectonic significance that has provided a conducive locale for circulation of mineralising fluids for gold and associated metals. The occurrence of albitite near Sakhun and Ladera suggests a deep, fracture-controlled, igneous emplacement and therefore is a conducive assemblage to host gold.

Lithostratigraphic relationships and the evolutionary model of the Aravalli Supergroup in Southern Rajasthan suggest that the geological setting of the Jhamarkotra and Delwara formations forms a conducive horizon to host copper-gold mineralisation. Gold occurrence in this litho-package has been reported recently in the Bhukia-Jagpura area in the Banswara and Dungarpur districts inviting the attention of not only Government organizations, but also multi-national exploration companies.

Advanced grass-root exploration has been conducted by an exploration agency using state of the art technology, including satellite imagery to less than 1m resolution, reprocessing of magnetic data, low level analyses of soil and stream sediment samples, reverse circulation-cum-diamond drilling and application of modern evaluation techniques with an estimate of precision. The systematic exploration work has strengthened the prospectivity of the area. In view of the conceptual model, future target areas for exploration of Gold and associated mineral can be identified.

Introduction

Gold is generally found in two types of deposits: lode (vein) or placer deposits; the mining technique used to extract the gold depends upon the type of deposit. Once extracted, the gold is refined with one of four main processes: floatation, amalgamation, cyanidation, or carbon-in-pulp. Each process relies on the initial grinding of the gold ore, and more than one process may be used on the same batch of gold ore.

Global resource of Gold indicates that 45% of the world resource is contributed by South Africa followed by Ghana at 17%, Australia at 8% and US at 5%, Figure 1. Occurrence of Gold has been reported throughout the stratigraphic column though most of the significant gold deposits are known to be hosted by the geological package of Precambrian age. The known belts are shown in Figure 2.

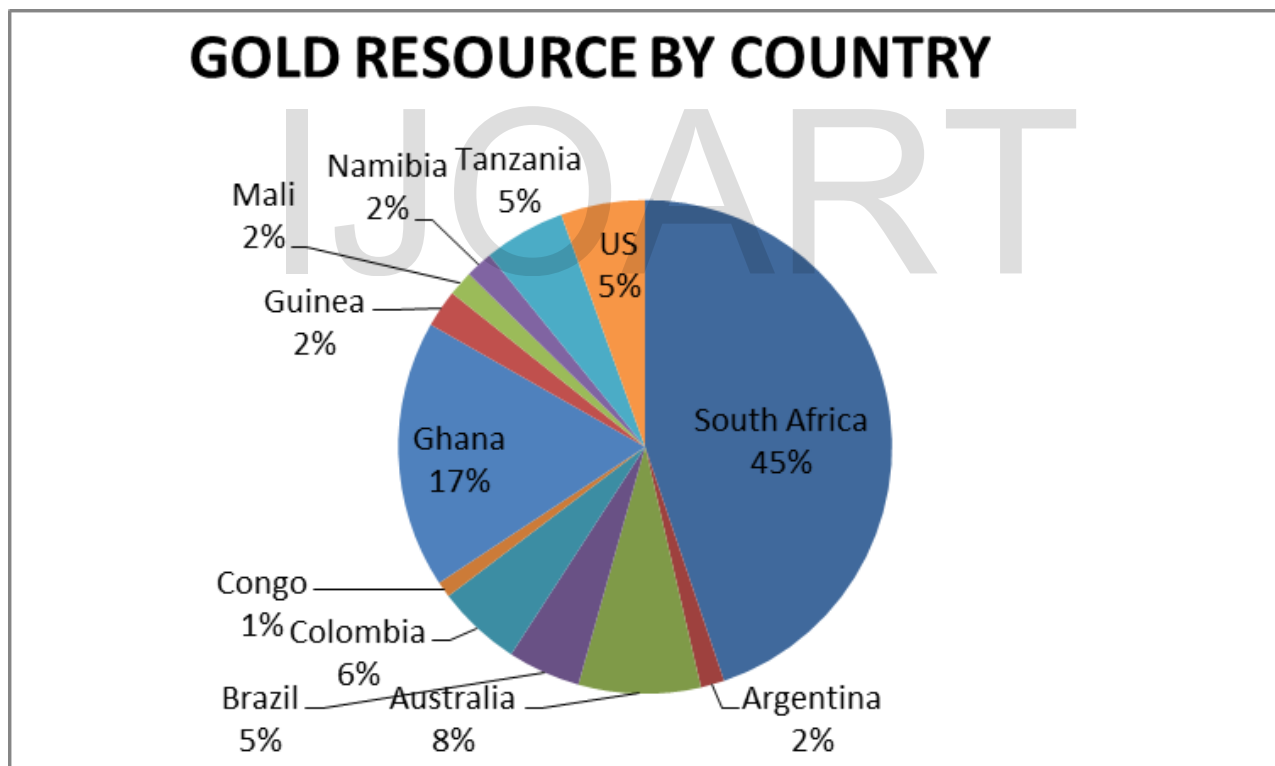


Figure 1: Global Gold resource (source: www.google.com)

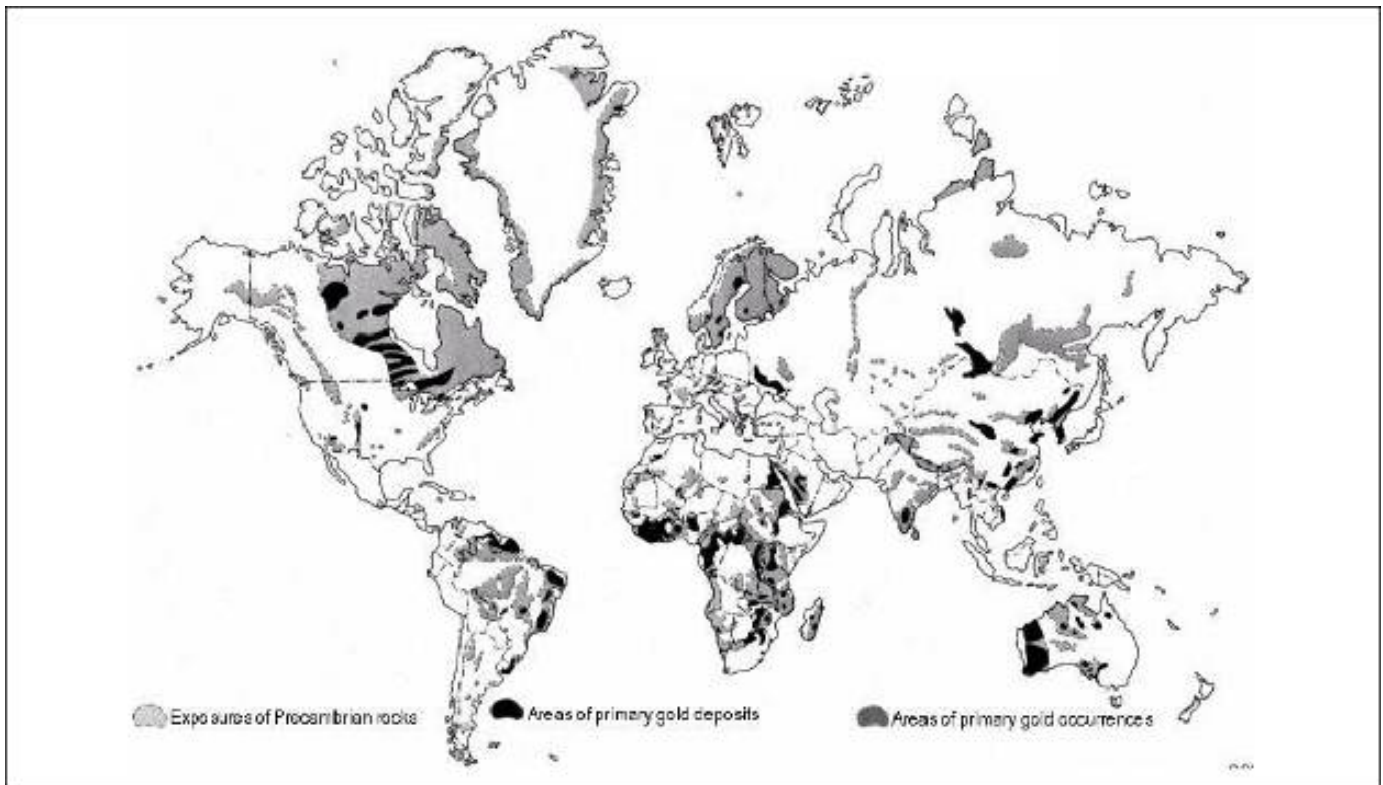


Figure 2: Gold deposits of Precambrian age (source [www. google.com](http://www.google.com))

Geological significance in Southern Rajasthan

The western segment of the Indian shield, which evolved through multiple process of crustal consolidation, reworking and development of cover sequence in intracratonic basins and continental margins with metallogenic imprints, is represented by the geologic assemblage of Rajasthan and Gujarat. Geoscientists had been engaged in contemplating the geological problems in respect of proper placement of stratigraphy, structure & tectonics, magmatism, metallogeny and crustal evolution. The geological time span for this craton is from Archaean to the Cenozoic, punctuated with significant geologic events of fold belt development and related mineralization.

The base metal mineralization in Rajasthan is most extensive as indicated by clusters of ancient workings and the present mining activity. Significant base metal mineralization is associated with Aravalli and Delhi group of rocks. A number of mineral belts have been identified based on geological attributes in terms of stratigraphy, tectonics, mineral assemblage and metamorphism. Number of published literatures is available on the stratigraphic set-up and the mineralization in the type areas (Deb & Bhattacharya 1980,

Mukharjee 1988, Poddar 1971, and others), but little work has been done on the gold mineralization hosted by the Paleoproterozoic sequence in Rajasthan.

Throughout the world, including India, metallogeny is related to magmatism and sedimentation in basins (eugeosynclines and miogeosynclines in the classical sense) during the entire Precambrian from Archeozoic to Proterozoic. In India, the Precambrian metallogenesis shows a variation in terms of type of mineralization, concentration of metals and mineralogical characteristics in different basins, though there are a few pronounced similarities as well. The Aravalli cratonic belt represents an important and significant terrain having unique geologic and metallogenic attributes. Exploration for gold and other noble metals in southwest Rajasthan has been taken up with increased tempo since last one decade mainly by Geological Survey of India. This has not only added to the mineral inventory of the Rajasthan State, but also could draw attention of the exploration and mining sector for diversification in exploration and mining of gold in the State. Known Gold occurrences are shown in Figure 3.

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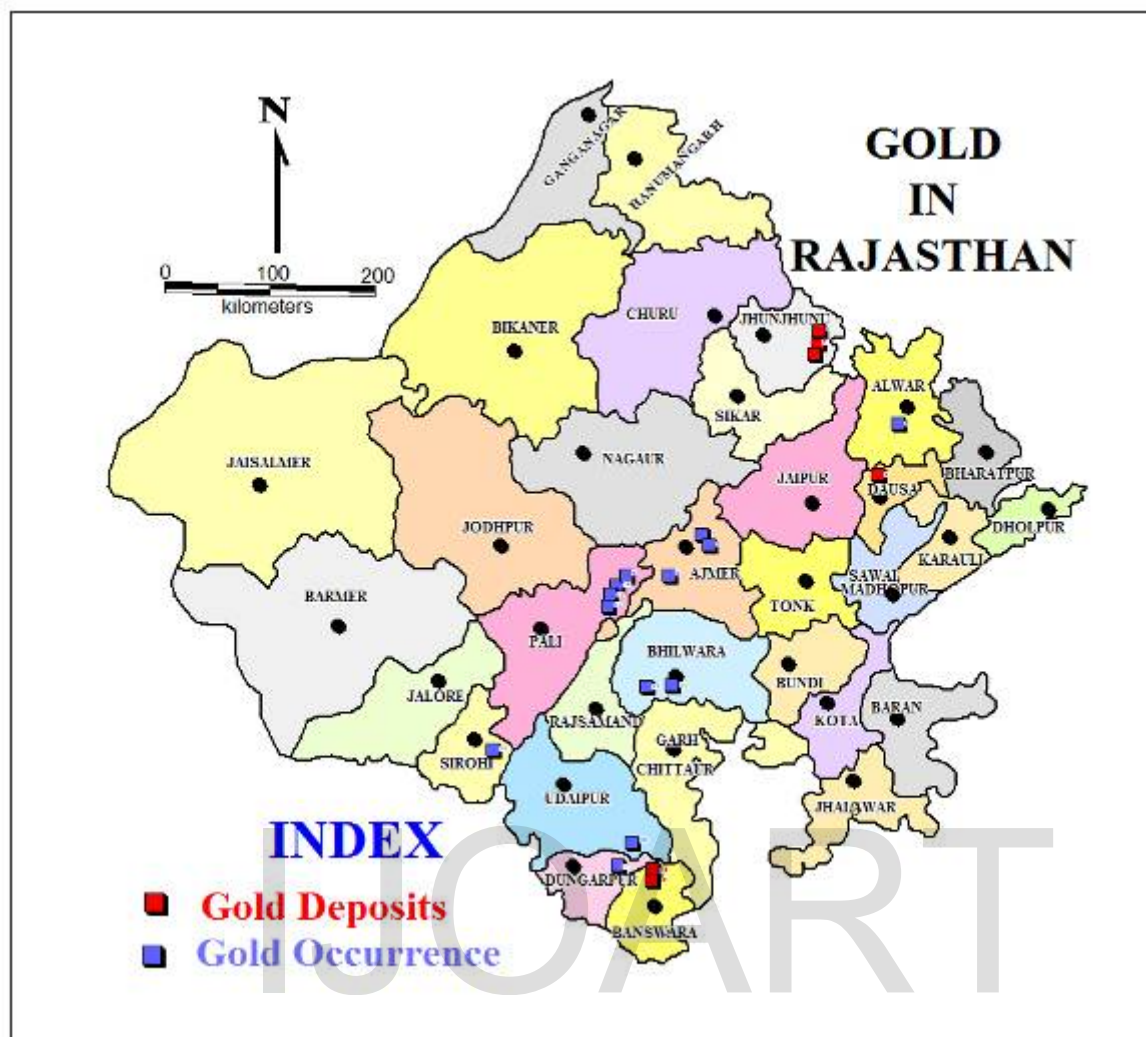


Figure 3: Known Gold occurrence in Rajasthan (After DMG, Rajasthan)

Geological set-up

The geological assemblage of Rajasthan includes a multi-litho-association representing the basement complex (BGC of Heron, 1953), Proterozoic fold belts (Aravalli & Delhi belts) and late Proterozoic igneous suit (Malani, Jalore and Siwana). Banded gneissic complex being the basement underlies the Proterozoic supracrustals of Aravalli and Delhi super groups. On the east BGC is truncated by the Great Boundary Fault (GBF), which marks the western limit of the Vindhyan system (Fig 4). Heron’s (1953) proposition that the BGC (with its meta-sedimentary and meta- igneous component) was already a deformed and metamorphosed rock suit during Archaean event was supported by Sharma (1988) on the basis of petrological and geological evidence. However, it is generally agreed that both basement and cover sequence of

Aravalli and Delhi super groups were subsequently deformed and recrystallized during the Aravalli orogeny thus considering the fact that Aravalli and Delhi Supergroup participated in the orogeny although their sedimentation was not contemporaneous. The recrystallized early crust subsequently rifted to develop basins of Proterozoic supracrustals of the Aravalli and Delhi super groups. The basinal sediments and the volcanics were deformed and metamorphosed to produce the Proterozoic fold belts of Aravallis and Delhis. Reworking of the middle Archaean rocks is evidenced by the recurrent events of granitic plutonism. There had been a continuous effort from the academicians and professionals to define the sequence of events chronologically, but still there are certain grey areas to be resolved.

Gold metallogenesis: Gold metallogenesis is related to greenstone belts. The greenstone belts were developed mainly during Archaean and Paleoproterozoic periods. The distribution of greenstone belts in India is not restricted solely to South India, but is also developed in four regions in Central India, though they are poorly exposed and have not been adequately studied. In Rajasthan, a Proterozoic greenstone belt has developed between the Aravalli range and Deccan Traps where a suite of metasediments and metavolcanics has been identified. The lithology identified as Proterozoic greenstone belt in Rajasthan extends from Nathdwara in the north to Jhabua (Madhya Pradesh) in the south. Earlier Proterozoic mafic volcanic rocks occurring at the base of Aravalli Supergroup have been reported to have komatiitic, tholeiitic composition. Geochemical and geological evidences suggest a transitional nature of the basal Aravalli sequence between Archaean greenstone belts and suggested that basal Aravalli volcanic constituted an abortive attempt to form a Proterozoic greenstone belt. It has also been inferred that, during Middle Proterozoic, the subduction of oceanic lithosphere started along the northern margin of Dharwar – the Singbhum Craton and eastern margin of Marwar Craton which were welded together to form a curvilinear margin of Dharwar – Singbhum

– Marwar proto-continent. However due to lack of calc-alkaline series, it is suggestive that, the Subduction was abortive and basin closure terminated in the upliftment of mountain belt comprising Aravalli –Delhi and Bijawar-Satpura. Sharma (1988) proposed a model of large-scale ‘ensialic orogenesis’ for the evolution of Aravalli mountain belt. In this model, the development of large ocean basins, characteristic of the Aravalli Delhi sediments, is visualized to have formed as a result of ductile extension of hot sialic material rather than by brittle rupture, which was followed by contraction of crust, rather than subduction of plate collision, resulting in

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deformation, metamorphism and partial melting of rocks at deeper levels. The above derivations reveal that, the ductile shearing and basement melting could be conducive geological features for emplacement of gold and other metals in a favourable litho-assemblage.

Tectonic lineament: Landsat imagery and aero-magnetic lineaments in the Indian shield indicate a tectonic stress field dominated by compression along a N-S direction, except in parts of the Aravalli region where the stress field is characterized by a E-W direction (Gupta and Bhattacharya, 1991). The prominent lineaments in the area are: Phulad lineament, Delwara lineament and Banas lineament. All these lineaments depict zones of discontinuity of tectonic significance that might have served as conduits for emplacement of intrusive bodies of varied dimension beneath the shield. Where the lineaments intersect may be an important area to look for high temperature minerals (Fig 3) (Radhakrishna 1989, Raja et.al 1993, Singh and Chaudhary 1998).

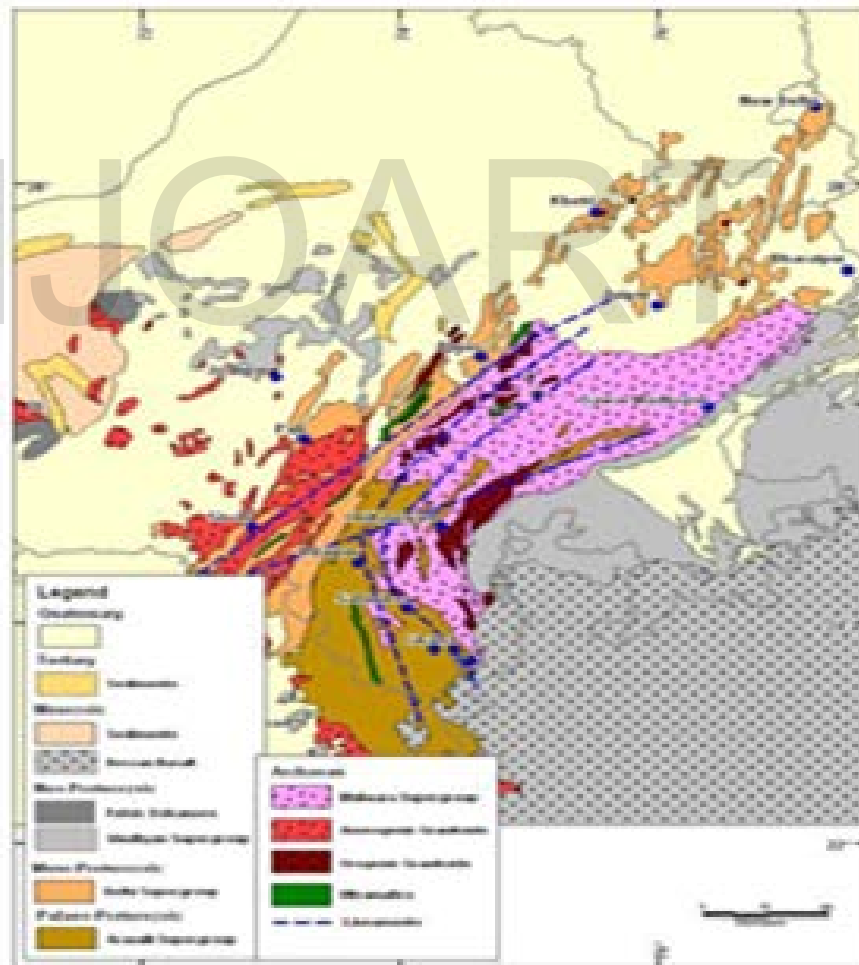


Figure 4: Geological map of NW India showing tectonic lineaments

The occurrence of albitite has been reported by Ray (1989) from the Precambrian terrain near Dudu, in Jaipur district, and a deep fracture-controlled emplacement of the rock was suggested by him. Albitite dykes near Sakhun and Ladera grade to quartz-albitite characterized by bluish, vitreous, quartz aggregates. Ray (1987) has indicated that the albitite of the Khetri Copper belt occurs within a 20 km long and 6 km wide zone forming a lineament. The occurrence in Dudu establishes an extension of this lineament for a further 100 km. Combined, this emerges as a major crustal feature of northern Rajasthan. The Geological Survey of India has reported the occurrence of copper and gold (0.1-2.6 g/t) in Ladera-Sakhun area. Recent exploration in Jagpura-Bhukia prospect in Banswara district has revealed that Albitite forms a major host for Gold mineralization. The occurrence of Albitite has been traced further south of Banswara near Jhabua thus establishing the fact that Albitite forms a linear tectonic lineament extending from Jhabua in Madhya Pradesh through Banswara in Southern Rajasthan up-to Khetri in north Rajasthan. The zone of albitite therefore, is a conductive tectonic assemblage to host gold in Southern Rajasthan Figure 4.

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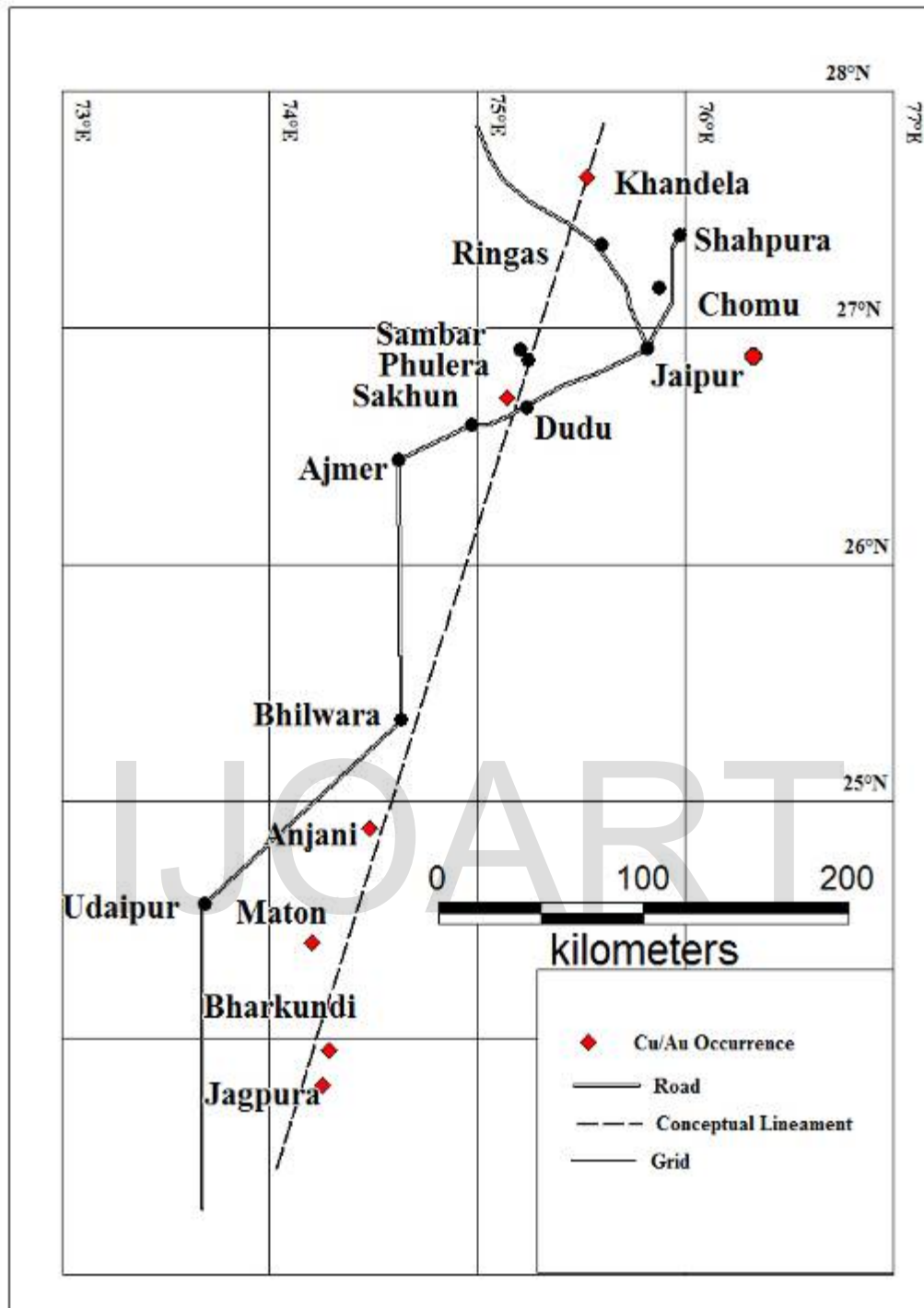


Figure 5: Interpreted generalised line passing through albitite and Cu-Au occurrences

Litho-Stratigraphic relationship: South-western Rajasthan comprises mainly the Proterozoic sequence of metavolcanic and metasedimentary rocks lying unconformable over the Archaean basement (Roy, 1988). A complex history of deformation in the Aravalli Supergroup has been elucidated by a number of workers (Naha and Chaudhary, 1986; Mukhopadhyay and Sengupta,

1979). Roy and his associates (Roy et. al., 1980; Paliwal, 1988; Roy and Bejarnia, 1990; Roy, 1996) conclusively proved the role of ductile shear zones and faults in the structural evolution of the rocks of the region. A few of the shears and faults have been considered as basin margin faults. Differential mobility of the underlying basement rocks during polyphase deformation episodes has been described by Roy and Nagori (1990) from the area east of Udaipur. Different models of stratigraphic succession have been proposed for the Aravalli rocks (Heron 1953; Mathur, 1964; Banerjee, 1971; Gupta et. al., 1980; Roy et. al., 1988). Comparison of these models brings to the fore considerable disagreement on the stratigraphic succession of the litho-stratigraphic relationship. It is generally agreed that the Aravalli Supergroup includes two contrasting sequences – a shelf sequence and a deep water sequence (Roy and Paliwal, 1981). In the shelf sequence, the Lower Aravalli Group is considered to comprise two formations – the Delwara Formation and the Jhamarkotra Formation, each represented in the type areas of Delwara and Jhamarkotra respectively (Roy et. al., 1988).

The Delwara Formation comprises green schist and metasediments that pass upward into the Jhamarkotra Formation of a carbonate association. The phosphorescent bed in the Jhamarkotra Formation forms a marker horizon within the carbonate sequence in the type area. Occurrence of copper and uranium mineralization within the carbonates and placement of elemental phosphate with the stromatolites in a shelf suggest a possibility of volcanic episode in the sea (Choudhuri and Roy, 1986). Metavolcanic rocks are observed as a continuous zone from south of Ghatol in Banswara district to Nathdwara in the north and constitute the basal sequence of Aravalli Supergroup. The stratigraphic sequence and the metallogenic setting suggest that the sequence is conducive for gold mineralization that is further evidenced by the discovery of gold prospects in Bhukia-Jagpura (Grover and Verma, 1993).

The geological setting of the Jhamarkotra and Delwara formations can be compared with the Proterozoic geological assemblage of Australia (Woodall, 1990). The early Proterozoic basins of Australia (Rutland et. al. 1990) are typified by three tectono-stratigraphic sequences comprising a basal sequence dominated by clastic and/or volcanoclastic units of limited lateral extent considered to be rift facies; a sequence of finer clastics with carbonates and other chemical sediments; and a sequence dominated by quartz-rich to volcanoclastic flysch facies. The litho-tectonic setting of the Australian middle to lower Proterozoic sequence is quite similar to that of the Lower Aravalli Group of Southern Rajasthan.

Table 1: Stratigraphic succession of the Lower Aravalli Group (based on Roy et. al., 1988)

	Formation	Lithology
Lower Aravalli Group	Jhamarkotra Formation	Dolomite, quartzite, phyllite, carbonaceous phyllite, Stromatolitic phosphate with copper and uranium ore bodies
	Delwara Formation	Chlorite schist and amphibolites (metamorphosed lava flows and tuffs), with interbeds of phyllite, dolomite, quartzite, local conglomerate, etc.
	First order unconformity	
Mewar Gneiss, Sarara granite gneiss, Ahar and Udaisagar granites.		

The Paleoproterozoic sedimentary sequence has been reported to have the potential for gold of Witwatersrand type and the Telfer type along major rift zones.

Recent exploration findings

Recent investigation in the area around Jagpura-Bhukia, Barkundi, Hinglazmata, Dagucha and Salumbar in Banswara and Dungarpur districts using state of the art technology including satellite imagery to less than 1m resolution, reprocessing of magnetic data, low level analyses of soil and stream sediment samples and reverse circulation and diamond drilling has established significant occurrence of Gold hosted by Jhamarkotra formation. Numerous ancient workings are found within the area extending from Amar Singh-Ka-Guda to Hinglazmata and Salumbar. Very little slag is found around these workings suggesting that the main target was gold rather than copper or iron (Unpublished MMI Report-1995; HZL 1993)

CONCLUSIONS

The metallogenic belts in southern Rajasthan have similarity in terms of their age, metal association and geological setting except the grade of metamorphism and metal content. Base metal deposits/prospects so far known are re-discovered mainly on the basis of surface manifestations and no significant discovery except very few, have yet been made by technology in-put. Modern exploration technology is required to be applied for discovery of deep-seated prospects with revised working geological models. The experience gained with the exploration methods to date demonstrates that they are invaluable for formalising exploration models, for providing a basis of communication between individuals with differing backgrounds and perspectives, for quantifying spatial associations of mineral occurrences with data layers, and for identifying prospective areas for follow-up investigations

The integrated exploration in-put in the southern Rajasthan by Government and nongovernment organisations through geological mapping combined with interpretation of satellite imagery and airborne magnetic data has resulted in an improved regional structural synthesis and model for the mineralisation style. A prognostic approach based on multiple parameters including working hypothesis would provide additional targets for investment on exploration leading to new discoveries. The petrology and trace element data suggest a magmatic component to this mineralisation.

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