Economic Mineralization
K.L. Shrivastava (Editor)
2009. pp. 15-25
Scientific Publishers (India), Jodhpur

2

Section-I

The Malani Supercontinent : Middle East Connection During Late Proterozoic

NARESH KOCHHAR

Centre of Advanced Study in Geology, Panjab University, Chandigarh 160014, India
Email : nareshkochhar2003@yahoo.com

Abstract

The Trans Aravalli Block (TAB) is unique in the geological evolution of the Indian Shield as it marks a major period of anorogenic bimodal, high heat producing, Intra-Plate magmatism represented by the Malani Igneous Suite (50,000 Km^2, 732 Ma). The Arabian Nubian Shield (ANS) is an accreted terrain composed of crustal domains of island arc, oceanic and continental affinities overlain by post accretionary sediments and volcanics. The paper discusses the similarities between the two, in the configuration of the Malani Supercontinent, to provide a new approach for the search of economic mineralization.

Both, TAB and ANS are showing characteristic presence of alkali granites at 732 Ma and Ca. 700 Ma, respectively. The emplacement of these granites and associated volcanics is controlled by ring structures, a menifestation of plume activity and cauldron subsidence, an evidence of extensional tectonic environment. Both the terranes preserve remnants of archean crust i.e. BGC of amphibolite facies (3.2 Ga) in TAB and trondjhemite (2.6 Ga) in ANS. This older crustal protolith has acted as precursor to the younger alkali granites, which in both the terranes mark the cratonisation of the shield. Both the terranes show evidence of strutian glaciation.

In both the terranes, there is characteristic similarity in the occurrence of peralkaline and peraluminous granite hosted mineralization of U, Th, Nb, Ta, REEs, Sn, W, Li and F etc. In this respect they are akin to the younger mineralized granites of Nigeria. Also, both the terranes are characterized by the occurrence of evaporite carbonate sequence of economic importance.

Keywords : Malani, Trans Aravalli Block (TAB), Arabian Nubian Shield (ANS), Mineralization, Alkali granite, Strutian glaciation, Mantle Plume.

INTRODUCTION

The Indian subcontinent is composed of three main geotectonically different blocks or terrains, the South Indian Block (SIB), the Bundelkhand block (BB) and the Trans-Aravalli block (TAB) (excluding, Central Indian and Eastern Indian Blocks) which were juxtaposed and sutured during different periods of Earth's history. The TAB and BB are geologically less related to each other are separated by NE-SW trending 700 km long Proterozoic Aravalli-Delhi mobile belt. The paper discusses the similarities between the Arabian shield and the Trans-Aravalli block of the NW Indian shield in the configuration of the Malani

Supercontinent in terms of alkaline magmatism, ring structures and Precambrian glaciation including sedimentation at near equatorial position to provide a new approach for the search of economic mineralization in the light of new tectonic settings.

The Trans-Aravalli Block: The TAB (west of the Aravalli-Delhi mobile belt) is unique in the geological evolution of the Indian shield as it marks a major period of anorogenic (A-type) bimodal, high heat producing, "Intra-Plate magmatism" represented by the Malani igneous suite (50,000km^2; 732Ma) comprising peralkaline (Siwana), metaluminous to mildly peralkaline (Jalor) and peraluminous (Jhunjhunu and Tusham) granites with cogenetic carapace of acid volcanics (welded tuff, rhyolite, breccia, perlite etc.). The magmatism is characterized by volcano-plutonic ring structures and radial dykes (Fig.1). The suite is bimodal in nature with minor amounts of basalt flows, gabbro and dolerite dykes. The Siwana ring structure (25.6 km NS and 31 km EW) is the most spectacular feature of the Thar desert and it coincides with the low velocity anomaly centred around Sarnu-Dandali, and Mer-Mundwara, Rajasthan, representing fossil plume head (Kennett and Widiyantoro, 1999). The Malani magmatism is controlled by NE-SW trending lineaments of fundamental nature and owes its origin to the Malani Plume (Kochhar, 2000,2004 Bhushan, 2000). The representatives of Malani magmatism also occur at Kirana Hills, and at Nagarparkar in Pakistan. (Qasim Janet al., 1997)

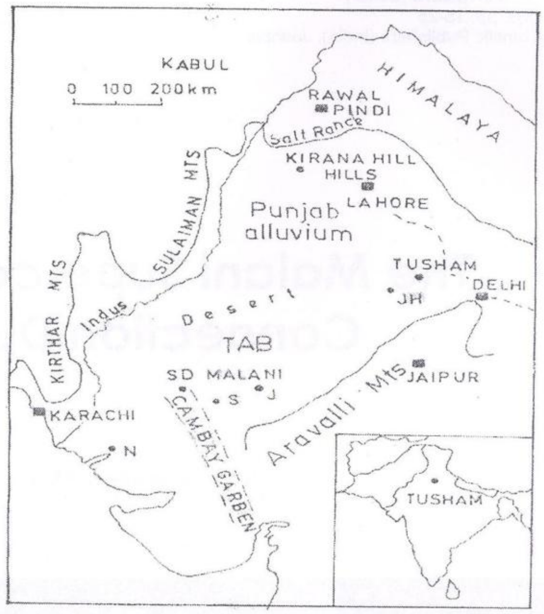

Fig. 1 Location map of the Malani igneous sutie . S: Siwana; J: Jalore, JH: Jhunjhunu; SD: Sarnu-Dandali, N: Nagarparkar; MM : Mer-Mundwara. TAB : Trans-Aravalli Block

The Arabian-Nubian Shield :

The Arabian Nubian shield (ANS) is an accreted terrane composed of crustal domains of island arc, oceanic and continental affinities overlain by post accretionary sediments and volcanics, and invaded by voluminous intrusions. The Saudi Arabia part of the Arabian-Nubian shield has been divided into five terranes separated by four suture zones. The three terranes i.e. Asir, Hijaz, Midyan west of the Nabitah suture zone are of ensimatic character, whereas, eastern two i.e. Afif and Ar-Rayan are of continental to marginal continental character (Fig. 2). The three ensimatic terranes are collectively referred to as Arabian-Nubian arc terranes (Stoesser, 1986).

Most of the shield was created in two distinct stages. These are (1) Island arc stage (between 660-900 Ma) in which subduction related processes operated for the generation of magma, and (2) a post accretionary stage (between 550-700 Ma) where magma was generated by fusion of continental protolith (Stoesser, 1986). According to Jackson (1986) the post accretionary stage is marked by the presence of granitic intrusions. According to Stern (2004) the evolution of the Arabian-Nubian shield occurred between 870 Ma and the end of Precambrian (ca.542Ma) and the crustal growth encompassed a time of dramatic climatic change.

In sourthern Yemen, the amalgamation of the two terranes ie. Abas (west) and Al-Mahfid (east), separated by Al Bayda island arc sequence, is marked by the 760 Ma magmatic activity (White house et al., 2004). According to Johnson and Kattan (2004) the Asir terrane is more closely linked structurally and tectonically with East African orogen, Madagascar, Ethiopia, Somalia, Yemen and Eritea than with the northern Shield, and that the southern and northern Arabian shields may be decoupled.

The remnant of the Archean crust as Proterozoic basement has been reported on the basis of lead isotope studies in the Afif terrane. A zircon from trondjhemite along the Al Amar fault has yielded 2067±74 Ma age there by indicating Late Proterozoic

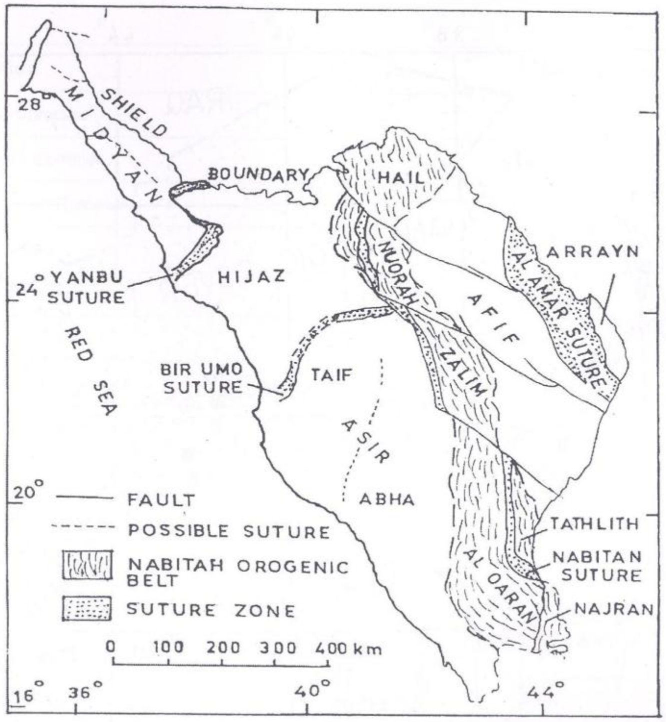

Fig. 2 Map of the Arabian shield showing terranes, provinces and Nabitah orogenic belt.

crust in the shield. Granodiorite gneiss from Jabal Khida in the easternmost part of the shield has been dated at 1629± 20 Ma (Stoesser, 1986).

According to Stoesser et al., (2004) there is no indication of crust formation between 1670-900 Ma as indicated by U/Pb and single zircon data. Between 760-740 Ma ago, the Khida terrane separated from the margin of Paleoproterozoic and Archean continetal block-the Arabian craton, presently concealed beneath the Phanerozoic cover in the east but exposed in Yemen.

Magmatism

The Arabian-Nubian shield contains one of the largest fields of alkali granites in the world. Forty nine major and more than a dozen minor alkali granite plutons occur in the Midyan and Hijaz terranes and in the Nabitah orogenic belt. The alkali granites do not occur in the SW and easternmost part of the shield. These alkali granites, emplaced over a span of 180 Ma, between 680-510 Ma ago, constitute the last phase of intrusives here. They are spatially associated with meta-aluminous subsolvus granites which form the core of the complex, and with a swarm of alkali rhyolite dykes in the northeast part of the shield (Stoesser and Ellion, 1985). A total of thirty three ring complexes and funnel shaped intrusions have been recognized related to the extensional teconic regime in the Arabian-Nubian shield. (Fig. 3) The magmatism (670-570 Ma) is mainly peralkaline to metaluminous with A-type affinity. The granites and the related rock types were emplaced by cauldron subsidence which operated in the final stage of cratonisation of the Arabian shield (Roobal and White, 1986).

The peraluminous and peralkaline granites with A-type geochemical characteristics are encountered at Jabal-Al Hasasin, Jabal-As Sawal, Jabal-Dahul (Stoesser et. al., 2004). According to Vail and Kuron (1978) high level ring complexes, ring dykes and cone sheets have been reported from the Red Sea Hills and Bayuda desert in NE Sudan. These complexes comprise granites, quartz-syenite, nepheline-syenite gabbro etc have been dated at 700 Ma. The Abas terrane is dominated by 760 Ma granitoids, (Whitehouse et. al., 2004), with Sm-Nd model age (2.3 Ga) indicating rework of a Paleoproterozoic or older crustal precursor.

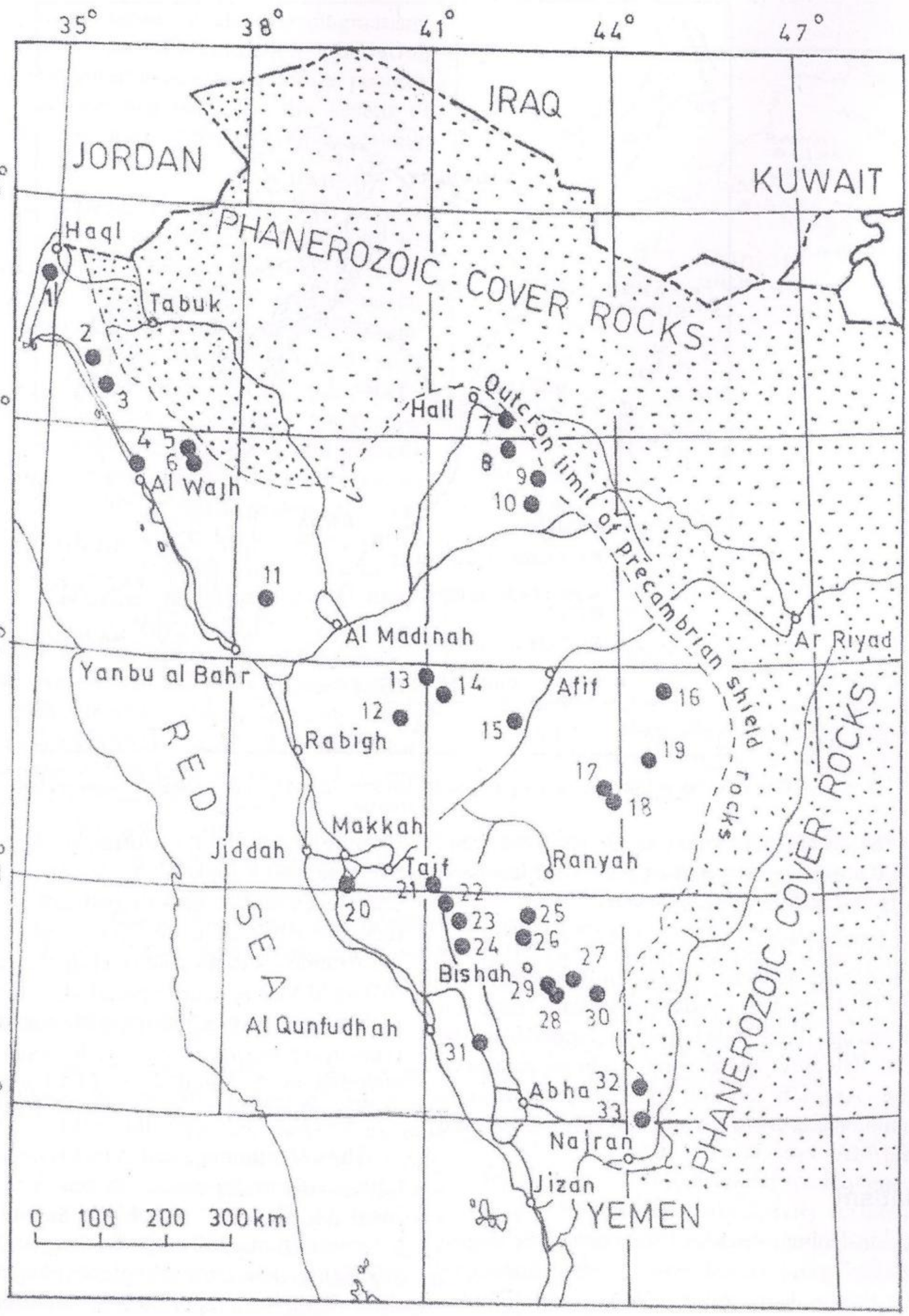

Fig. 3 Map Showing the location of Ring Complex (RC), Single Ring Structure (SR), Beljar Plutons (BJP) and Calderas (C) in the Arabian Shield. Number refers to the locations.

Table for Fig. 3

Sr.No.	Location	Type	Geochemical Affinity
1	Sawda Complex	RC	AA
2	Dabbagh Complex	RC	AA
3	Sulay Siyah Complex	RC	P
4	Liban pluton	BJP	P
5	Habd Complex	BJP	P
6	Warid Complex	RC	AA
7	Jabal Salma Complex	C	AA
8	Jabal AL-Makhrugah	SR	P
9	Jabal Raha	C	AA
10	Jabal Silrilah	SR	AA
11	Martabah Comples	RC	P
12	Jabal Ramram	C	P
13	Jabal Hadash Shara	RC	P
14	Jabal Hadbad Dayahm	RC	AA
15	Jabal as Safwah	RC	AA
16	Jabal Arawan	RC	AA
17	Jabal Kursh	RC	AA
18	Jabal Dahul Complex	RC	AA
19	Uyaijah ring dyke	RC	AA
20	Unnamed Complex	RC	P
21	Jabal Al-Qunnah	RC	P
22	Unnamed ring dyke	SR	AA
23	Khutamah ring dyke	SR	P
24	Aquq ring dyke	SR	P
25	Jabal Munirah	RC	P
26	Jabal Al Najiah	RC	P
27	Jabal Bani-Bisqan	RC	AA
28	Jabal Al-Hasser	RC	AA
29	Jabal Refdah	RC	P
30	Unnamed Complex	RC	P

Table for Fig. 3 Cont.

31	Lakathah Complex	RC	P
32	Wadi Idimah Complex	RC	AA
33	Jabal Ashirah Complex	RC	AA

AA : Alkaline affinity, Syenite, alkali granite with Riebeckite, aegirine etc. A-type. P Peraluminous / metaluminous affinity.

Mineralisation

The alkali granites of the Arabian-Nubian shield have been compared with those of Jos Plateu of Nigeria and Niger in terms of mineralisation. Alkali granites and microgranites and their hydrothermal derivatives are associated with disseminated and vein deposits of Nb, Ta, Sn, and REEs commonly accompanied by Th, U and F. Mineralisation is generally disseminated in porphyritic microgranitic stocks eg. Ghurayyah and Ummal Birak, or concentrated in apical or marginal layered pegmatitic-aplite complex eg. Jabbal said and Jabal Sumr al Ishar. Galena veins containing fluorite are also encountered at Jabal Hadb ad Dayahen (Jackson, 1986). The aluminous granites host rich deposits of Nb, Th, REEs, Li, Zr etc.

According to Ramsay (1986) there are four specialized felsic plutonic rocks in the Arabian-Nubian Shield i.e agpaitic, plumastic, calcic and miaskitic corresponding to alkali granite, alkali-feldspar granite, monzogranite and syenitic precursors. These granites host Nb-Zr-REE, Sn-W-Ta-Mo-Be and Mo-W-Bi-Pb, Zn-Ag respectively.

Malani Supercontinents

The Malani plume which gave rise to the Malani magmatism some 732 Ma B.P. was responsible for the separation of TAB from the East Gondwana and subsequent amalgamation of the Malani supercontinent comprising TAB of the Indian shield, Arabian Nubian, shield, Central Iran, Somalia, Seychelles and Madagascar and south China (Fig. 4) (Kochhar, 2001, 2004, 2006). It has been suggested that all these microcontinents were characterized by a common crustal stress pattern, rifting and thermal regime evidenced by the occurrence of widespread magmatism of alkali granites and comagamtic acid volcanics in the TAB of Indian shield (Kochhar, 2004), Central Iran (Forster, 1987), ANS (Kroner, et. al., 1989), Somalia, (Kroner et. al., 1989), Madagascar (Yoshida et. al., 1999), Seychelles (Hoshino, 1986), (Ashwal et. al., 2002, Torsvic et al., 2001, Li et. al., 2003).

Interestingly Forster (1987) compared the Infra-Cambrian and Cambrian rhyolites and the associated granites of Central Iran with the Malani rhyolites and the Pan-African granties of Arabian shield. The similarity has been attributed to the Gondwana connection based on paleomagnetic data. Central Iran held a position south of equator during Infra Cambrian and later drifted from the southern margin of the Gondwanaland to its present position as a microplate. According to Kroner et. al., (1990), the period between 850-750 Ma represents the most significant crust formation event in all parts of ANS including Somalia in the form of felsic intraplate magmatism. Rogers (1990) has also suggested that both Indian shield and Arabian-Nubian shields are similar in their development including production of alkali granites, subsidence of thick partly deformed basin on recently formed crust and ultimate development of plateform cover sediments.

Paleomagmatism and Sturtian glaciation :

The ubiquity of alkali magmatism in all the above Middle East countries, together with their comparable paleomagnetic data, and the common occurrence of carbonates, phosphorites and evaporites all strongly support an amalgamated landmass the Malani supercontinent (Fig. 4). The carbonate evaporite facies of the Hauqf Supergroup form a belt of evaporite basin and intervening carbonate plateform which can be traced in these microcontinents: Hormuz Series of Arabian Gulf and southern Iran, Infra - Cambrian carbonate plateform in Central Iran, Ghabar Group of South Yemen, India Ad Series of Somalia, Wadi Fatima Series and Abla Formation, South Arabia Saramuj Formation of Jordan, Salt Range Formation, Pakistan, and evaporites of Nagaur-Bikaner basin and subsurface evaporite and anhydrite sequence of SW Punjab and Haryana, India (Fig. 5) (Gorgin et. al., 1982, Kochhar, 2004, 2006). The Huaqf axis formed a barrier between evaporites an carbonate platform and or anhydrite plateform. The Oman-Ural megalineamnet controlled the distribution of evaporite-carbonate sequence.

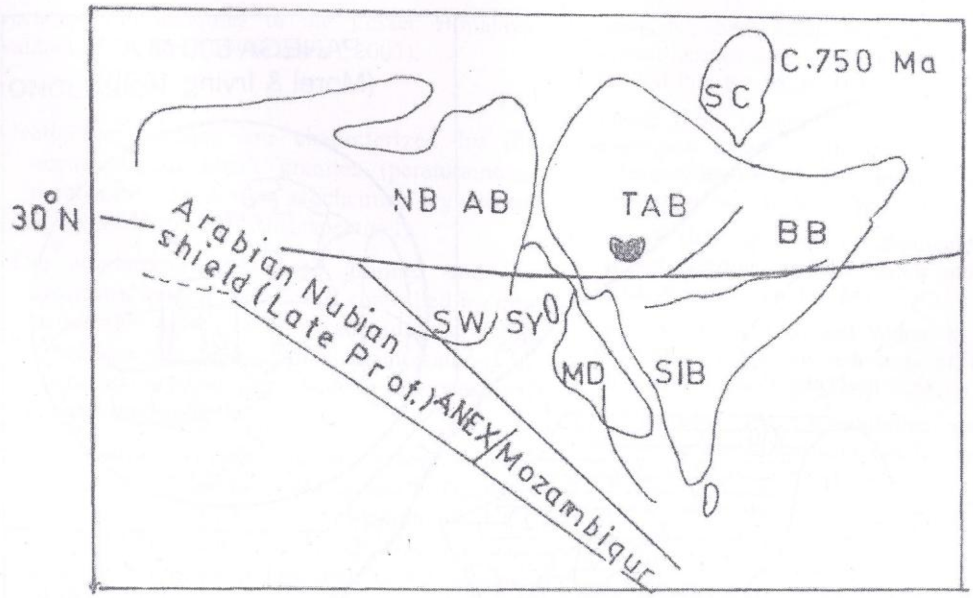

Fig. 4 Assembly of the Malani supercontinent.
NB : Nubian Arabian shield.MD : Madagascar, SM : Somalia, SC : South China, SY : Seychelles, BB : Bundelkhand block, SIB : South Indian block,TAB : Trans-Aravalli block

The APWP paleomagnetic pole at ca 800 Ma place South China at 55-70° N at par with high paleolatitudes of India during Malani rhyolite period (ca.750 Ma) (Li et al., 2004 Torsvic et al., 2001). The impact of the Precambrian glaciation which had covered vast areas of the globe including India, located at that time in the Mid to Low latitude equatorial zone, is evident in the occurrence of glacial boulders the Pokhran glacial boulder beds (Chauhan et al., 2001, Pareek, 1984, Paliwal and Rathore, 2000). The boulders of Malani granites also occur in the Salt Range. In the Yangtze craton, Linntua and Nantua deposits are also of glaciogenic origin. Kilner et al., (2005) have identified glacial and interglacial cyclicity within the Haqf supergroup, which has been attributed to low latitude glaciation. (Stern et al., 2004)

Around 700 Ma B.P. India, which still remained part of East Gondwana, was located in the tropical latitudes around 600 Ma (Powell et al., 1993). The combined 800-700 Ma polar wander path implies pole to equator rapid velocities of 20 cm per year for India and South China (Li et al., 2004). During this period the northern margin of India were subjected to desiccation. The carbonate mainly dolomite and phosphate deposits of Late Sinian-Late Precambrian age in Yangtze block corresponds with Hanseran evaporites in the Marwar basin of TAB, SW Punjab, and Bilara phosphorites in Rajasthan (Sinha-Roy et al., 1998). According to Pandit et al., (2001) a carbonate isotopic profile for the lower part of the Bilara carbonate rocks show marked oscillations and a broadly negative $\delta^{13}C$ as low as <-4.3% PDB in the lower unit of this Group and <-6.5% PDB in the overlying middle unit. The upper part of the profile shows a gradual positive shift. The ^{13}C shifts observed are related to the ^{12}C-dependent marine biota, whose population radically decreases during glacial period and proliferates with the onset of interglacial spells. This consequently leads to oscillations in the ^{13}C values corresponding to the changing uptake of ^{12}C by life present. Such shifts in the C-isotopes are well preserved in the marine carbonates of the period. For example, the extremely low ^{13}C values in Bilara carbonates indicate glacial related cold climatic conditions, with the positive shift in the carbon isotope values in the upper formation implies a warmer climatic conditions during the later period. The Bilara carbonate group carbon isotope profile have close correspondence with global carbon isotopic evolution curve in Haqf, Oman, Sibena platform, Mongolia and Morocco. According to Illyin (1990) the continental margin of Vendian-Early Precambrian supercontinent comprising South China, Kazakhstan, Mongolia were the sites of equatorial sedimentation in the form of shallow water

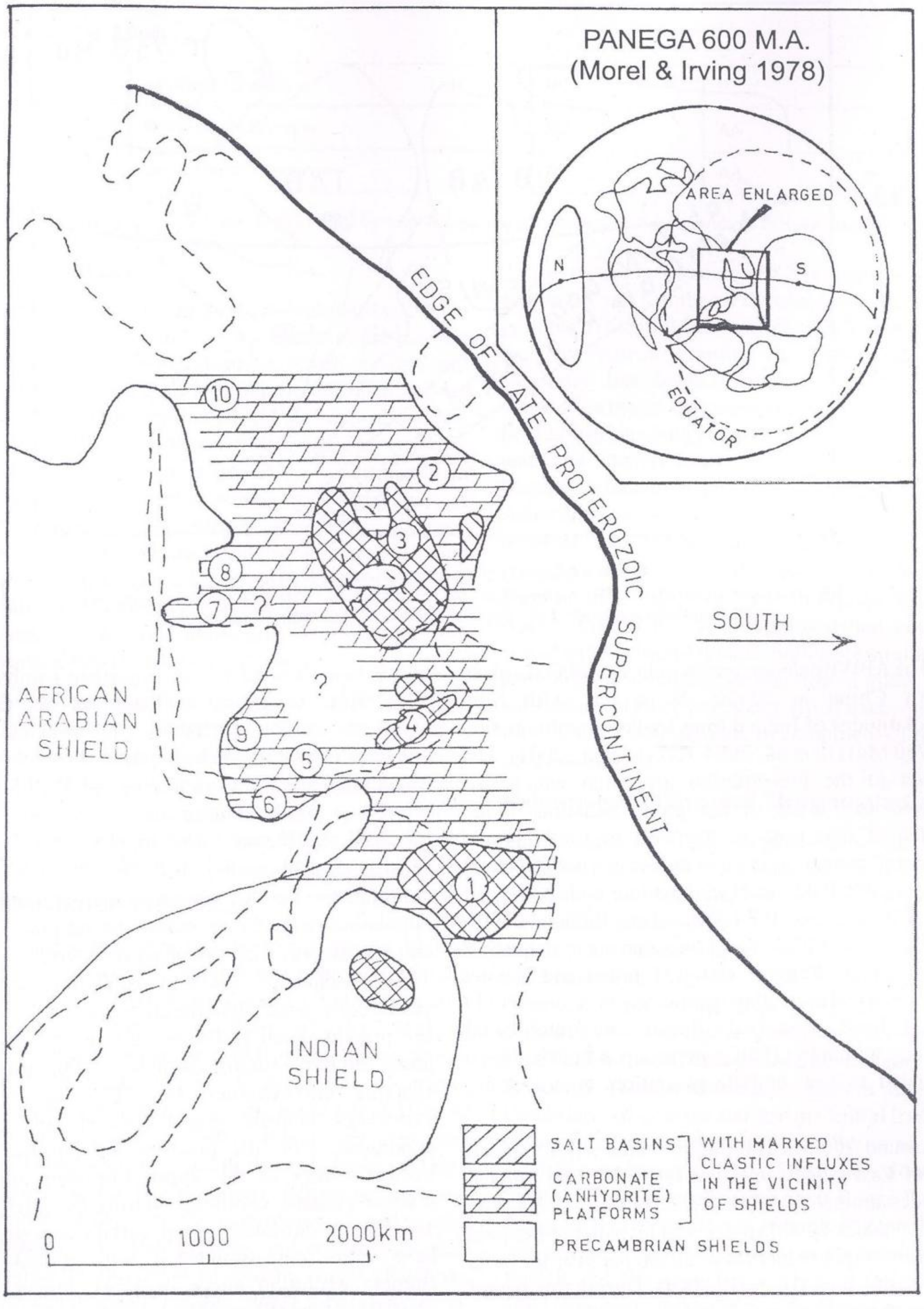

Fig. 5 Paleogeography of the Late Precambrian Early Cambrian sediments. Number refers to the locations.

carbonate and phosphorite deposits. Similar deposits also occur in the Lesser Himalaya (Banerjee and Mazumdar, 1999) (Kumar et al., 1997). Incidentally the Pokhran diamictite correlate with other

Precambrian diamictites in the Lesser Himalaya (Valdiya, 1995, Virdi, 1995, Tewari, 2003).

CONCLUSION

1. Both the terranes are characterized by the occurrence of alkali granites (peraluminous-peralkaline with A-type geochemical signatures) at 732 Ma and ca. 700 Ma respectively.
2. The emplacement of these granites and the associated acid volcanics was controlled by ring structures and cauldron subsidence. Ring complexes are the contineta1 manifestations of plume activity and are indicative of extensional tectonic environment.
3. Both the terranes preserve the remnants of Archean crust i.e. BGC of amphibolitic facies (3.2 Ga in the TAB (Kochhar, 2004) and trondjhemite of 2.6 Ga in the Afif terrane of ANS. This óIder crustal protolith has acted as precursor to the younger alkali granites.
4. In both the terranes the alkali granites mark the cratonisation of the shield.
5. Both the terranes are characterized by similar peralkaline and peraluminous granite hosted mineralisation of U, Th, Nb, Ta, REEs, Sn, W, Li and F etc. In this respect they are akin to the younger granites of Nigeria. (Kochhar,1998, 2000 and Vallinayagam, 2004, Somani 2006).
6. Both the terranes are characterized by the occurrence of evaporites-carbonate sequence and show evidence of Strutian glaciation.

The aforesaid similarities can only be explained if the Arabian-Nubian shield was attached to the Trans-Aravalli block of the Indian shield around 600-700 Ma B.P. in the configuration of the Malani Supercontinent.

ACKNOWLEDGEMENTS

I am thankful to Prof. K.L. Shrivastava for inviting me to contribute this paper to the Prof. B.S. Paliwal commemorative volume.

References:

Ashwal, L.D. Demaiffe, and Torsvic, J., 2002, Petrogenesis of Neoproterozoic granitoids and related rocks from the Seychelles, the case for an Andean-type arc origin, J. Pet., v. 43, no. 1, pp. 45-84.

Banerjee, D.M., and Mazumdar, A., 1999, On the Late Neoproterozoic- Early Cambrian transition events in part of east Gondwanaland. Gond. Res., v. 2, pp. 199-211.

Bhushan, N., 2000, Neoproterozoic magmatism of the Malani igneous suite, W. Rajasthan, India, Geol. Surv. Ind. Spl. Pub. No. 55, pp. 319-332

Chauhan, D.S., Mathur, K.M., Narayan Ram, 2001, Geological nature of the Pokaran Boulder Bed : Paleoenvironmental, paleoclimatic and stratigraphic implication Jour. Geol. Soc. Ind. v. 58, pp. 425-433.

Forster, H., 1987, Ignimbrite cauldrons, alkali granites and mineral deposits in fault block mountains. Geol. Rundsch., v. 76/2, pp. 373-388.

Gorin, G.E., Racz, L.G; and Walter, M.R, 1982, Late Precambrian-Cambrian sediments of Hugf Group. Sultanate of Oman. AAPG Bull. V. 68, pp.2609-2627.

Hoshimo, M., 1986, Amphiboles and coexisiting ferromagnesian silicates in granitic rocks in Mahe, Seychelles. Lithos, v. 9, pp. 11-21.

Ilyin, A.V., 1990, Proterozoic supercontinent, its latest Precambrian rifting, breakup, dispersal into smaller continents and subsidence of their margins: Evidence from Asia Geology, v. 18, pp. 1231-1235.

Jackson, N.J., 1986, Petrogenesis and evolution of Arabian felsic plutonic rocks, Jour. African Earth Sci., v. 4, pp.47-50.

Kennett, B.L.M. and Widiywantro, S., 1999, A low velocity wavespeed anomaly beneath northwestern India: A seismic signature of the Deccan plume? Earth Planet Sci. Lett., v. 165, No. 1, pp. 145-156.

Kilner, B., Macniocaill; and Brasier, M., 2005, Low latitude glaciation in the Neoproterozoic of Oman. Geology v. 33, pp. 413-416.

Kochhar, N., 1998, Rare metal potential of the A-type Malani Granties, NW peninsular India, Ind. Mineral, v. 52, pp. 271-276.

Kochhar, N., 2000, Attributes and significance of the A-type Malani magmatism, northwestern peninsular India. In M.Deb (Ed.) Crustal Evolution and Metallogeny in the northwestern Indian shield, Chapter 9, pp. 183-217, Narosa Publishing House, New Delhi.

Kochhar, N., 2001, Anorogenic magmatism, mantle plume and assembly of the Late Proterozoic sueprcontinent, NW Indian shield. GRG/CIGE Misc. Publ. No. 12, pp. 22-27.

Kochhar, N., 2004, Geological evolution of the Trans-Aravalli Block (TAB) of the NW Indian shield: constraints from the Malani igneous suite (MIS) and its Seychelles connection during Later Proterozoic. Geol. Surv. Ind. Spl. Pub. No. 84, pp. 247-264.

Kochhar, N.,2006, The Malani supercontinent : Middle East connection during Late Proterozoic. 6th International Conference on the Geology of Middle East. Al Ain, UAE, Abstract, p. 230.

Kochhar, N., 2007, was Yangtze craton, South China attached to the Trans-Aravalli block of the NW Indian shield during Late Proterozoic ? Curr. Sci. vol. 92, No. 3, pp. 295-297.

Kroner, A., Eyal., M., and Eyal, Y., 1990, Early Pan-African evolution of the basement around Elat, Isreal, and the Sinai peninsula revealed by single zircon evaportion dating, and implications for crustal accretion rate. Geology, v. 18, pp. 545-548.

Kroner, A., Reischmann, T., Tojt, Y., Zimmer, M., Stern, R.J., Hussein, U., Mansour, M., Eyal, M., Eyal., Y., and Sassi, P. (1989) Timing mechanism and geochemical pattern of arc accretion in the Arabian-Nubian shield and its extension into Isreal and Somalia. Extended Abstr. 28th IGC, Washington, DC, USA, v. 2, p. 2/231.

Kumar, G., Shanker, R., Maithy, P.K., Mathur, V.K., Bhattacharya, S.K., and Jani, R.A., Terminal Proterozoic-Cambrian sequences in India: a review with special reference to Precambrian-Cambrian boundary. Paleobot., v. 46, pp. 19-33.

Li, Z.X., Evans, D.A.D., and Zhang, S., 2004. A 90° spin on Rodinia: possible casual links between the Neoproterozoic supercontinent. super plume, true polar wander and low latitude glaciation. Earth Planet Sci. Lett., v. 220, pp. 409-421.

Li, Z.X., Li, X.H., Kinny P.D., Wang, J. Zhang, S., Zhov, H., 2003, Geochronology of Neo-proterozoic syn-rift magmatism in the Yangtze craton, sourth China and correlation with other continents: evidence for a mantle super-plume that broke up Rodinia. Precamb. Res., v. 122, pp. 85-109.

Li, Z.X., Li, X.H., Kinny, P.D., and Wang, J., 1999, The breakup of Rodinia, Did it start with a mantle plume beneath south China. Earth Planet. Sci. Lett., v. 173, pp. 171-181.

Paliwal, B.S., and Rathore, P.S., 2000, Neoproterozoic volcanics and sedimentaries of Jodhpur, A reappraisal In K.C. Gyani and P.Kataria (Eds.) Tectonomagmatism, geochemistry and metamorphism of Precambrian terrain University Press, Udaipur, pp. 75-96.

Pandit, M.K., Sial, A.N., Jamrani, S.S., and Feroeira, V.P., 2001, Carbon isotopic profile across the Bilara group rocks of trans-Aravalli Marwar supergroup in Western India : Implications for Neoproterozoic Cambrian Transition Gond. Res., v. 4, pp. 387-391.

Pareek, H.S., 1984, Pre-Quaternary geology and mineral resources of north-western Rajasthan, Mem. Geol. Surv. Ind., v. 115, pp. 1-99.

Powell, C.Mc A., Li, Z.X., McElihiney, M.W., Meert, J.G. and Park, J.K., 1993, Paleomagnetic constraints on timing of the Neoproterozoic breakup of Rodinia and the Cambrian formation of Gondwana geology, v.2, pp. 889-892.

Qasim Jan, M., Lachari, A., and Asif Khan, M., 1997, Petrography of the Nagar Parkar igneous complex, Tharparkar, SE Sindh Geol. Bull. Univ. Peshwar, v. 30, 227-249.

Ramsay, C.R., 1986, Specialized felsic plutonic rocks of the Arabian shield and their precursors. Jour. African Earth Sci. v.4, pp. 153-168.

Rogers, J.J.W., 1990, Comparison of India and Nubian shield. In S.M.Naqvi (Ed.) Precambrian continental crust and its economic resources. Development in Precambrian Geology, 6, Elsevier, New York.

Roobal, M.J. and White, D.L., 1986, Caldera subsidence and Caldera above Arabian felsic plutons : a preliminary survey. Jour. African Earth Sci. v. 4, pp. 123-134.

Sinha-Roy, S., Malhotra, G., and Mohanty, M., 1998, Geology of Rajasthan, Geol. Soc. Ind. Publ. Bangalore. 278p.

Somani, R.L., 2006, Evolution of the tin-tungston and copper-bearing hydrothermal solutions associated with Tusham igneous compelx, Bhiwani, Haryana: a fluid inclusion study. Jour. Geol. Soc. Ind., v.67, pp. 379-386.

Stern, R., Avigad, D. Beyth, M., Gebresilassie, S., Kuster, D., Mehare, K., and Miller, N., 2004, The Neoproterozoic Snowball earth hypothesis and the Arabian Nubian shield, 32nd IGC, Florence, Italy, Scientific sessions : Abstract (part2), p. 1191.

Stoesser, D., Whitehouse, M., and Stacey, J., 2004, Neoproterozoic evolution of the Khida terrane: Saudi Arabia : A detached microplate of the Arabian Shield, 32nd IGC, Florence, Italy, Scientific sessions : Abstract (part2), p1190.

Stoesser, D.B. 1986, Distribution and tectonic setting of plutonic rocks of the Arabian shield. Jour. African Earth Sci. v. 4, pp. 21-46.

Stoesser, D.B. and Elliott, J.E., 1985, Reconnaissance geology of the Al-Qasr Quadringle, sheet 27/41C Kingdom of Saudi Arabia, Open file Report USGS-OF-05/2, Scale 1:100,000

Tewari, V.C., 2003, Sedimentology, paleobiology and stable isotope chemostratigraphy of the terminal Neoproterozoic Buxa dolomite, Arunchal Pradesh, NE Lesser Himalaya, Him. Geol. v. 24, pp. 1-18.

Thomson, P.R., and Kattan, F.N., 2004, Geochemistry and structural reappraisal of the Asir Terrane assembly, S. Arabia Shield, 32nd IGC, Florence, Italy, Scientific sessions : Abstract (part2), p1190.

Torsvic, T.H., Carter, I.M., Ashwal, L.D. and Bhushan, S.K. Pandit, M.K. and L.D. Jamtveit, B., 2001. Rodinia refined or obscured : paleomagnetism of the Malani igneous suite, N.W. India Precamb. Res., v. 108, pp. 319-333.

Vail, J.R. and Kuron, J.L., 1978, High level igneous emplacement in the Red Sea Hills, Sudan Geol. Runds. v.

67, pp. 521-530

Valdiya, K.S., 1995, Proterozoic sedimentation and Pan-African geodynamic development in the Himalaya. Precamb. Res. v. 76, pp. 35-55.

Vallinayagam, G., 2004, A report on rare-metal and rare cartus in the Siwana ring complex, Rajasthan, Jour. Applied Geochem. v.6, pp. 387-391.

Virdi, N.S., 1999, Co-existing Late Proterozoic glacigene sediments and evaporites in the Lesser Himalaya and eastern Indian shield expression of contemporaneity of low latitude glaciation and tropical dessication. In B.S. Paliwal (Ed.) The Indian Precambrian, Scientific Publishers, Jodhpur, pp. 502-511.

Whitehouse, M., Flowerdew, M., Windley, B., Al-Khirbash, S., and Ba-Bttat, M., 2004, The Al Bayda arc, Yemen : A 200 Ma record of Neoproterozoic accretion at the eastern margin of the Arabina-Nubian shield. 32nd IGC, Florence, Italy, Scientific sessions : Abstract (part2), p1190.

Yoshida, M., Rajesh, H.M., and Santosh, M., 1999, Juxtaposition of India and Madagascar : a perspective, Gond. Res. v. 2, pp. 449-467.

Hon'ble Reviewers

1. Prof. S.C. Sarkar
   (Former Head)
   Emeritus Scientist
   Department of Geological Sciences
   Jadavpur University
   KOLKATA 700 032 INDIA

2. Dr. A.V. Sankaran
   10, P & T Colony
   I Cross, II Block
   R.T. Nagar
   BANGALORE 560 032 INDIA

Editorial Assistance

Dr. Virendra Gaur