CHAPTER I

INTRODUCTION

The geology of Rajasthan presents an excellent example encompassing rocks of all the ages right from the earliest crustal component to the recent. The four fold classification of the Precambrian rocks of Rajasthan (Heron, 1953) envisages the geological evolution through three major orogenic cycles represented by the rocks of the Banded Gneissic Complex (BGC), the Aravalli Supergroup and the Delhi Supergroup (called systems earlier), respectively (Fig. 1.1). This sequence remains the basic framework of reference despite certain revisions in the local stratigraphic sequence and regional correlation due to later investigations.

There have been mainly five periods of acid magmatism in Rajasthan as summarized by Choudhary et al. (1984). These periods have been placed at (1) 3000-2900 Ma, (2) 2600-2500 Ma, (3) 2000-1900 Ma, (4) 1700-1500 Ma, and (5) 850-750 Ma.

The Banded Gneissic Complex (BGC) marks the basement in Rajasthan which must predate 3000 Ma as one of the intrusives in it, i.e. Untala granite, east of Udaipur, has been dated as 2950 ± 150 Ma by Choudhary et al. (1984). Further, Gopalan et al. (1990) have found Sm-Nd evidence of 3307 ± 65 Ma old biotite gneiss, Mewar Gneiss, from Jhamarkotra SE of Udaipur. Very recently Widenbeck and Goswami (1994) have also obtained high precision $^{207}Pb/^{206}Pb$ zircon age of 3281 ± 3 Ma for the orthogneiss from the same area. The base of Aravalli Supergroup has been indicated at 2000 Ma. The original Delhi rocks of Heron (1953) have recorded two magmatic events widely separated in space and time. While the earliest granitic activity at 1600 Ma has been recorded only in the Alwar basin in the northeast Rajasthan, the younger activity between 850- 750 Ma has been wide spread, as shown by the nearly concordant ages of *'Erinpura type'* granites along the Aravalli mountain range and the Malani rhyolites in the western plains of the Aravalli range (Choudhary et al., 1984).

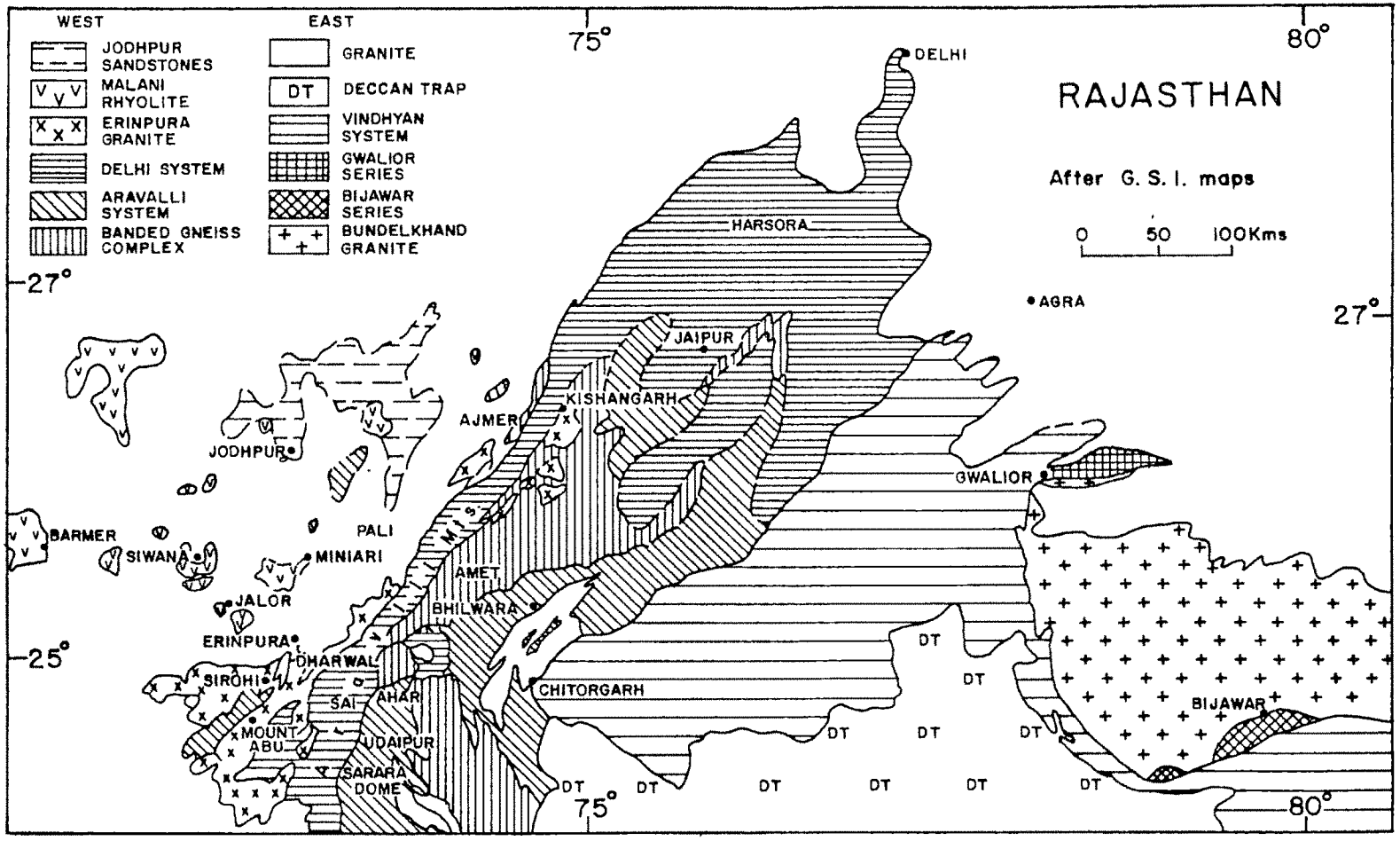

Fig. 1.1. Geological Map of Rajasthan (After G.S.I. Maps).

The term *Malani* was first introduced by Blanford (1877) for a group of volcanic rocks spread in parts of western Rajasthan, after Malani district of former Barmer State. The first and the only detailed account of Malani was given by La Touche (1902) who made detailed geological traverses in Pali, Jalore and Jodhpur districts of Rajasthan and provided petrographic description of the rocks. La Touche (1902) called it as *'Malani Igneous Suite'*. Coulson (1933) extended the limits of Malani to the State of Sirohi and named it as *'Malani System'* consisting of plutonic, hypabyssal, volcanic and tuffaceous rocks of varying composition. Pascoe (1960) retained the name given by La Touche. In recent times the term has rather been used loosely and various workers have used different connotations. Kochhar (1984) has continued the term *Malani Igneous Suite* while Srivastava (1988) has used *Malani Volcanic Province.* Bhusan (1991) called it as *Malani Igneous Complex.* However, we prefer to use the term Malani Igneous Province *(MIP)*, which has also been used by Chandrasekaran and Srivastava (1992), to cover all the igneous rocks (volcanic as well as plutonic) of varying composition from the area and the same terminology will be followed throughout the text.

The *MIP* marks the youngest Proterozoic tectonomagmatic event covering an area of about 50,000 sq. km in western and southwestern Rajasthan and perhaps continues in the Sind province of Pakistan. The Malani represents one of the largest volcanisms in India, second only to Deccan Traps, and the area covered extends from south of Sirohi to north of Pokaran and from east of Jodhpur to Pakistan International Boundary (Fig. 1.2). Contemporaneous volcanism has also been reported in Churu and Jhunjhunu districts of northeastern Rajasthan extending upto Tosham in Haryana (Kochhar et al. 1985).

The province consists dominantly of felsic volcanics (rhyolites) and their plutonic equivalents with minor occurrences of alkaline, basic, intermediate and peralkaline acid volcanics and plutonites. The rocks occur as inselbergs, tors and residual hill ranges from near east of Jodhpur upto the edge of the Thar desert of India covering a width of approximately 240 km. Since the volcanic rocks occur in parts of the Thar desert, most of the area remains blanketed by thick sand cover leaving only small exposed outcrops. The Malani volcanics overlie Proterozoic metamorphics of uncertain age (pre-Delhi or Delhi Supergroup) at many places in Pali and Sirohi districts and underlie the

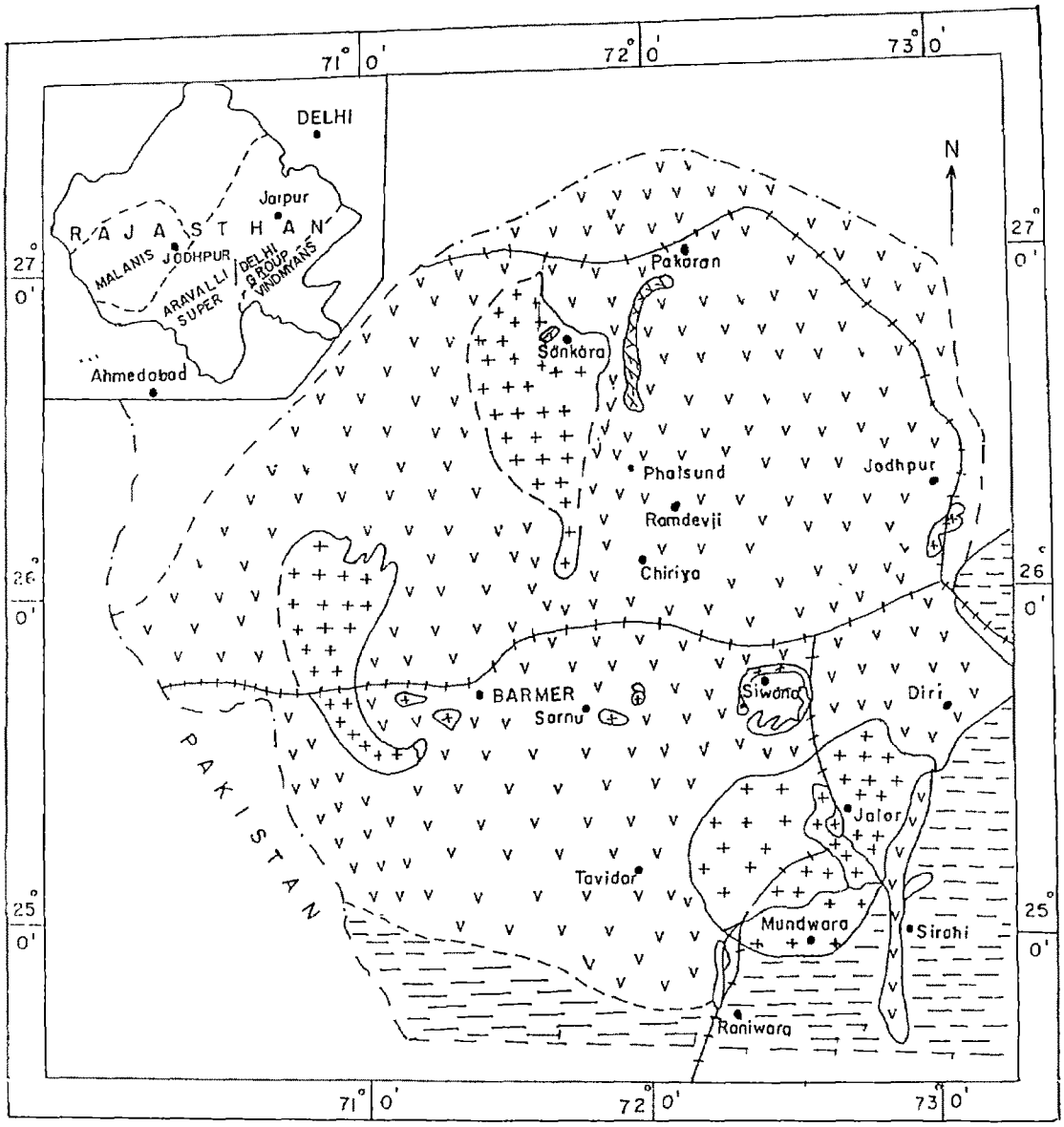

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Fig. 1.2 Geological Map of Malani Igneous Province, Rajasthan (After Bhusan, 1985).

Trans-Aravalli Vindhyans.

As regards the stratigraphic position of the province, Heron (1917), in his memoir on the geology of northeastern Rajputana, had suggested that the magmatic stocks of the Malani rhyolites are the batholithic granite (the Erinpura granite) intrusive into the Delhi rocks and that they were the product of fissure eruptions which inaugurated the uprising of the Aravalli chain. He, further, reported that the Malani rhyolites were contemporaneous with the upper most Delhis, since in Kirana hill (Sargoda, Pakistan), they are interstratified with sedimentaries of the Ajabgarh type. But subsequently, in the light of the work of Coulson (1933) and earlier work of La Touche (1902), Heron (1953) revised his opinion and suggested that the parent stocks of the Malani rhyolite were the Jalore and Siwana granite which also intrude Erinpura type of granite and that all the different igneous rocks of the province belong to a single Proterozoic magmatic event.

Regarding age of the ***MIP***, work of Crawford and Compston (1970) remains the major one. They dated the Malani rhyolites and related granites from Barmer, Pali and Jalore districts and gave Rb-Sr isochron age of 745 ± 10 Ma, thus, indicating a single magmatic event around 745 Ma ago. This was supported in recent years by Pareek (1981), Kochhar (1984) and Bhusan (1985, 1989). Further, two samples dated by Crawford and Compston (1970), one rhyolite and other granite, gave much younger model ages of 526 and 428 Ma, respectively. Based on this, they also suggested the possibility of existence of some younger flows and granites. The Tosham volcanics and associated granites have also given Rb-Sr isochron age of 745 ± 20 Ma (Kochhar et al., 1985)

It is noteworthy to mention here that the heterogeneous suite of ***'Erinpura type'*** granite, traditionally distinguished from the Malani rhyolites and associated high level granites (Heron, 1953), were however considered, despite their chemical incoherence, of the same age of about 740 Ma by Crawford and Compston (1970) and Crawford (1975). Further, the studies of Choudhary et al. (1984) demonstrated that the Erinpura proper granite and the suite of intrusive granites, all along the axial zone of Aravallis from Sendra in the north and Sai in the south, have ages in the time band of 800 ± 50 Ma. Jhunjhunu and Ambaji granites in the northeast and south Rajasthan are also of this generation. Though these ages are in the order of the Malani igneous province, a slightly

earlier time of formation of Erinpura granite is not ruled out (Choudhary et al., 1984).

However, the contention of ***MIP*** representing a single magmatic event is belied by the detailed petrographic and geochemical work done in the last decade by Srivastava and his co-workers from different parts of the Malani province, namely, Diri (25°37':73°02'), Gurapratap Singh (25°37':73°09') and Manihari (25°40':73°08') in Pali district, Tavidar and Karara (24°51': 72°09'; 24°54': 72°10') in Jalore district, Siwana (25°39': 72°25'), Sarnu-Dandali (25°45': 71°45') and west of Barmer town in Barmer district, and Mundwara (24°50': 72°33') in Sirohi district of Rajasthan (Fig. 1.2). The alkali vs. silica diagram (Fig. 1.3) and total iron vs. alumina plus calcium diagram (Fig. 1.4) of various rocks from these areas reveal that rocks from these localities plot along different trends belonging to four different associations (Srivastava, 1988). These associations are:

1. *Basalt-andesite-dacite-rhyolite association of Diri, Gurapratap Singh and Manihari (Pali district) (Fig. 1.3 and 1.4). Besides the normal rhyolites and rhyolitic tuffs, there are also some ultrapotassic rhyolites in the area which do not correspond to the main trend but plot alongwith some of the potassic rhyolites belonging to the association (3) which will be described below. Analyses of normal rhyolites from Barmer and Siwana and of Tosham volcanics given by Pareek (1986) also plot along this trend.*
2. *Comendite-pantellerite, sodatrachytes and associated peralkaline granites of Barmer and Siwana (Barmer district). These rocks show a steady increase in iron with decreasing alumina plus calcium or increasing peralkalinity, in contrast to the rocks belonging to association (1), which show a decrease in total iron with decreasing alumina and lime (Fig. 1.4).*
3. *Mildly alkaline trachy basalt-trachy andesite-trachyte-alkali rhyolite of Tavidar and Karara (Jalore district). These rocks are characterized by relatively high K_2O (Fig. 1.3). The dominant rock types of this association are the trachytes, quartz trachytes and the potassic rhyolites. The amount of the associated potassic andesites, hawaiites and mugearites is relatively small. Some of the mugearites post date the main phase of eruption.*
4. *Alkaline and hyperalkaline rocks including alkali pyroxenites, micro-melteigites,*

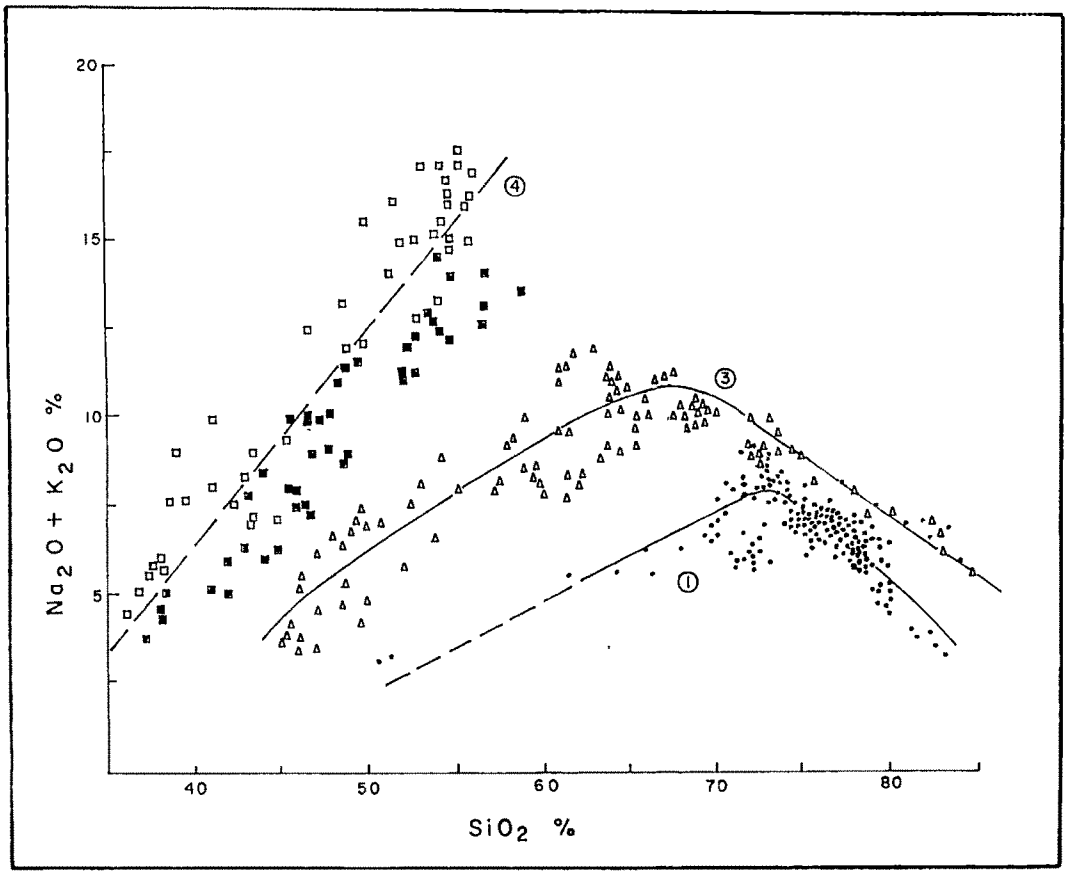

Fig. 1.3. AlK - SiO_2 Diagram of Various Rocks from the Malani Igneous Province (After Srivastava, 1988). Solid Circles : Basalt-Andesite-Dacite-Rhyolite from Gurapratap Singh and Diri (Pali District); Open Triangles : Trachyandesite-Trachyte-Alkali Rhyolite from Tavidar (Jalore District); Open and Solid Squares : Alkaline Rocks from Sarnu-Dandali (Barmer District) and Mundwara (Sirohi District), respectively.

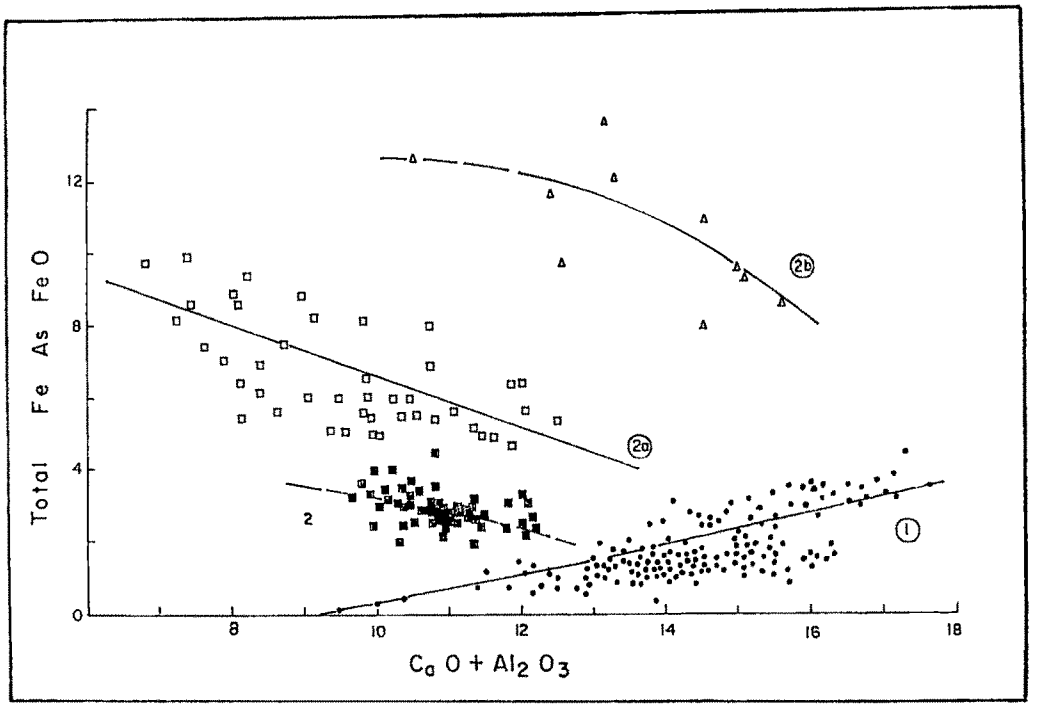

Fig. 1.4. FeO - Al_2O_3+CaO Diagram of Rhyolitic Rocks from Malani Igneous Province (After Srivastava, 1988). Solid Circles : Normal Rhyolites, Rhyodacites and Dacites from Pali, Barmer and South of Siwana; Solid Squares : Comendites from SE of Barmer town; Open Squares : Pantellerites and Peralkaline Granites from Siwana; Open Triangles : Soda Trachytes from Siwana.

ijolites, essexites, various foidal syenites, basanites, nephelinites, phonolites and carbonatites of Mundwara (Sirohi district), Sarnu-Dandali and west of Barmer town (Barmer district) (Fig. 1.3).

Bhusan and Sengupta (1979) have also reported four phases of Malani activity from Sankara, Jaisalmer. The first phase is represented by rhyolites and porphyry flows, while the second phase is a coarse grained biotite granite intruding into the first phase. The third phase includes both extrusive and intrusive rocks of acid and intermediate composition and the last phase is of intrusive basic rocks. Recently Chandrasekaran and Srivastava (1992) have also reported polyphase igneous activity, based on multivariate statistical analysis, for the ***MIP***.

As regards the time framework of vaious associations of Srivastava (1988), no work has yet been done. However, he has postulated that association (1) is oldest and coeval with the Erinpura granite phase. It overlies the pre-Delhi or Delhi Supergroup of rocks and extends from east of Jodhpur to the edge of Thar desert in the form of roughly NE-SW or NNE-SSW trending hills. The Jalore and Siwana type granites and the associated comendites and pantellerites of association (2), which occur in the areas of basement uplift and crustal upwarps (marked by Sarnu high and Therad high) (Fig. 1.5), represent younger sub-volcanic ring complexes typical of the areas of epeirogenic doming. The fact that they intrude the volcanics of association (1), and the presence of a strong thermal event between 500-550 Ma in resetting the mineral assemblages of the Erinpura type granites (Choudhary, 1984) and younger model Rb-Sr ages of 526 and 428 Ma for a rhyolite and granite from Barmer and Jalore, respectively (Crawford and Compston, 1970), taken together suggest that these granites represent a Palaeozoic event unrelated to Erinpura granites or the rhyolites of association (1).

The Tavidar and Karara rocks as well as the mildly alkaline rocks of the Sarnu-Dandali belonging to association (3), situated at the edge of the Sanchor basin and the Barmer graben respectively (Fig. 1.5), have been correlated to epeirogenic movements which started in the early Jurassic time and continued upto the end of Cretaceous. These epeirogenic movements led to subsidence and formation of the Kutch and Sanchor basins in the south and Jaisalmer basin in the central part of Rajasthan. The alkaline rocks

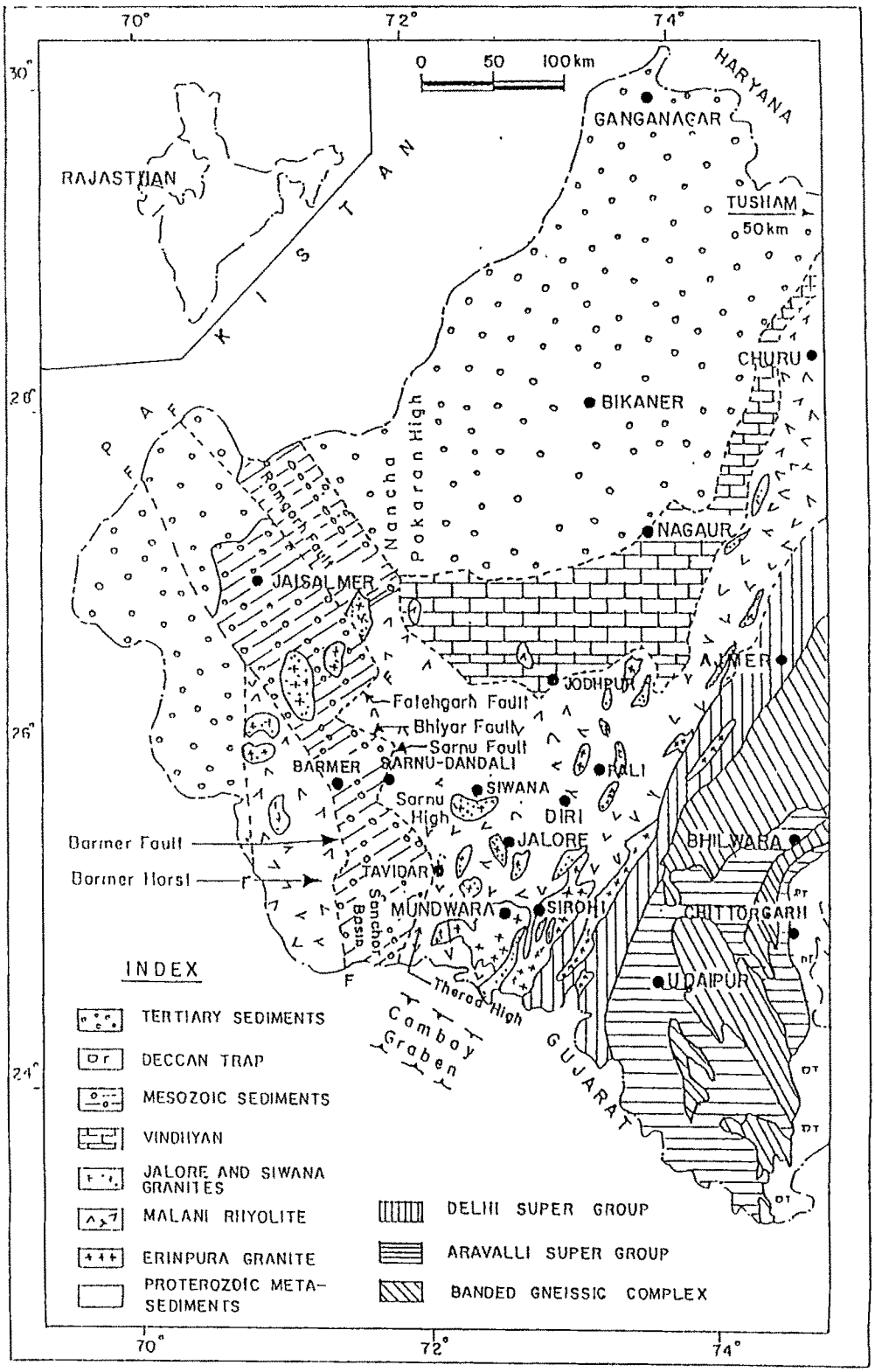

Fig. 1.5. Pre-Quaternary Interpretative Geological Map of Southwest Rajasthan (After Srivastava, 1988 : Superimposed on Structures of Dasgupta and Chandra, 1978).

marking the association (4) are the youngest and belong to a post-Cretaceous event (Srivastava, 1988). However, in the absence of any radiometric dates, the time framework to the different associations remain speculative. Keeping this in view the present study was undertaken. The present study is aimed at seeking answers to evolutionary and petrogenetic problems of the Malani igneous province of southwest Rajasthan through isotopic studies. Some of the pertinent questions that need to be answered are:

(a) *whether the different associations belong to a single magmatic cycle or they represent different magmatic episodes as envisaged by Srivastava (1988),*

(b) *what is the relationship between peralkaline (Siwana type) and peraluminous (Jalore type) granites/rhyolites and finally,*

(c) *what is the position of various magmatic episodes in the evolution of the Malani igneous province ?*

In other words, the main objective of the present study, is to provide precise time constraints to the various associations referred to above, using K-Ar, ^{40}Ar-^{39}Ar and Rb-Sr systematics, in order to construct an evolutionary model for the Malani igneous province of southwest Rajasthan.