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The crustal record in Rajasthan

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Abstract. Age determinations mostly by Rb/Sr whole rock isochrons of the Precambrian rocks of Rajasthan in northwest India are summarized and discussed. On present sampling and subject to its possible bias, the following conclusions can be made. The Untala Granite believed to be intrusive into the gneissic terrain (BGC) east of Udaipur has the oldest age, 2·95 b.y. yet measured for a granite in Rajasthan. This, coupled with the lead isochron age of 3·5 b.y. for detrital zircon from the Aravalli schists by Vinogradov and others extends the basement of Rajasthan well into the Archaean. The time equivalence of the BGC east of Udaipur with the Berach Granite dated only at 2·55 b.y. is not tenable. No satisfactory radiometric age control exists for the onset and duration of the Aravalli Supergroup, believed to be an early Proterozoic linear belt.

Heron's original Delhi Supergroup has recorded acid magmatism widely separate in space and time. The earliest activity between 1700 and 1500 m.y. is recorded mainly in the Alwar basin in northeastern Rajasthan while the younger activity between 850 and 750 m.y. is represented by the 'Erinpura type' granites in the central and southern Aravalli sector. This younger event not only has let its thermal overprinting on the older Alwar rocks but also marks the onset of emplacement of the Malani Igneous suite in the trans-Aravalli terrain. This raises the new possibility that the Delhi rocks of Heron represent atleast two chronologically independent sequences with varying geographical extent. The trans-Aravalli terrain is most probably floored by partly reworked, crystalline basement and developed along linear rift zones which acted as loci for high heat flow and igneous activity since about 800 m.y. ago.

Keywords. Precambrian rock; banded gneissic complex; geochronology; proterozoic linear belt.

1. Introduction

The crystalline Precambrians of Rajasthan consist of an old high grade gneissic basement, the Banded Gneissic Complex (BGC), flanked successively by two Proterozoic mobile belts, the Aravalli and the Delhi Supergroups, respectively. Such a combination in close juxtaposition provides an excellent opportunity to trace the crustal evolution in this part of the Indian shield from early to late Precambrian times. But no serious effort has so far been made either to establish the antiquity of the high grade complex or to assess the role of plate tectonics in the evolution of the proterozoic belts, as has been done elsewhere. Lack of reliable geochronological information in deciphering the sequence of events and chemical data bearing on the nature of the geological processes involved has been a serious handicap. The very recent attempt by Sen (1981) on the reconstruction of Proterozoic crustal evolution on plate tectonic models represents a very useful beginning, although the evidence cited is admittedly tentative.

This contribution presents a critical review of the available geochronological data for evidence of crustal remnants older than 3000 m.y. in Rajasthan and a distinct pattern of younger age provinces suggestive of plate tectonic origins.

2. Stratigraphy and tectonic setting

The Delhi and Aravalli Supergroups consist of folded metasediments, basic metavolcanis, and intrusives of basic and acidic composition, lying on the BGC of high grade gneisses and granites (Heron 1953). While the main Delhi Supergroup is exposed as a single continuous outcrop along the Aravalli Range, the Aravalli and the BGC outcrops exist as isolated patches with their narrow connecting links either masked under younger cover or obscured (figure 1). Later revisions to the original Heron's scheme of classification are mainly in respect of mutual correlation and relative stratigraphic position of the isolated outcrops. For example, the southern contact of the BGC in the north (BGC I) with the Aravalli metasediments around Nathdwara is only a migmatite front and hence the former is not pre-Aravalli in age (Naha *et al* 1967). The BGC II in the south and BGC III (Berach Granite) in east central Rajasthan, on the otherhand, are unconformably underlain by the Aravalli metasediments (Poddar 1965; Roy and Paliwal 1981; Roy *et al* 1981). The second revision considers Heron's eastern Aravalli belt through Bhilwara as older than the western Aravalli belt through Udaipur and calls the former together with the Berach Granite an older orogenic belt, the Bhilwara Group (Raja Rao 1970). This has very recently been upgraded into the Bhilwara Supergroup with the inclusion of BGC I and II (Gupta *et al* 1980). Sen (1981) has separated the foregoing two limbs of the Aravalli rocks into two subgroups based on tectonic and lithological differences but without attributing any significant time difference between the two. Sen (1981) has also split Heron's original Delhi Supergroup in the Central and Southern Aravalli Range into four tectonically and temporally independent belts piled one over the other.

The mutual conflicts among the various schemes proposed are yet to be resolved. Also the relationship of the Vindhyan platform deposit in the east and the Malani igneous complex to the west of the Aravalli Range to the development of the Proterozoic mobile belts has not been explored.

3. Methods of geochronology

Since the Rb/Sr whole-rock isochron method is the least ambiguous of all the methods so far applied to the geochronology of Rajasthan, the following discussion is based mainly on the whole rock isochron results. The Sm/Nd and U/Pb methods which have successfully been applied to other Archaean complexes are yet to be implemented systematically in Rajasthan. As direct dating of basic igneous and metamorphic rocks has not yet been possible due to their low Rb/Sr ratios, the work has so far been mainly on the granites in the various belts. Since the relationships of the granites to their host rocks are often obscured or even totally obliterated, considerable caution is to be exercised in the interpretation of granite isochrons. Figure 1 shows the age distribution of the Precambrian rocks of Rajasthan.

4. Discussion

Though the Precambrian rocks of Rajasthan are believed to be very old, it is not clear whether these are as old as those of Singbhum and Dharwar, dated at more than 3·4 b.y.

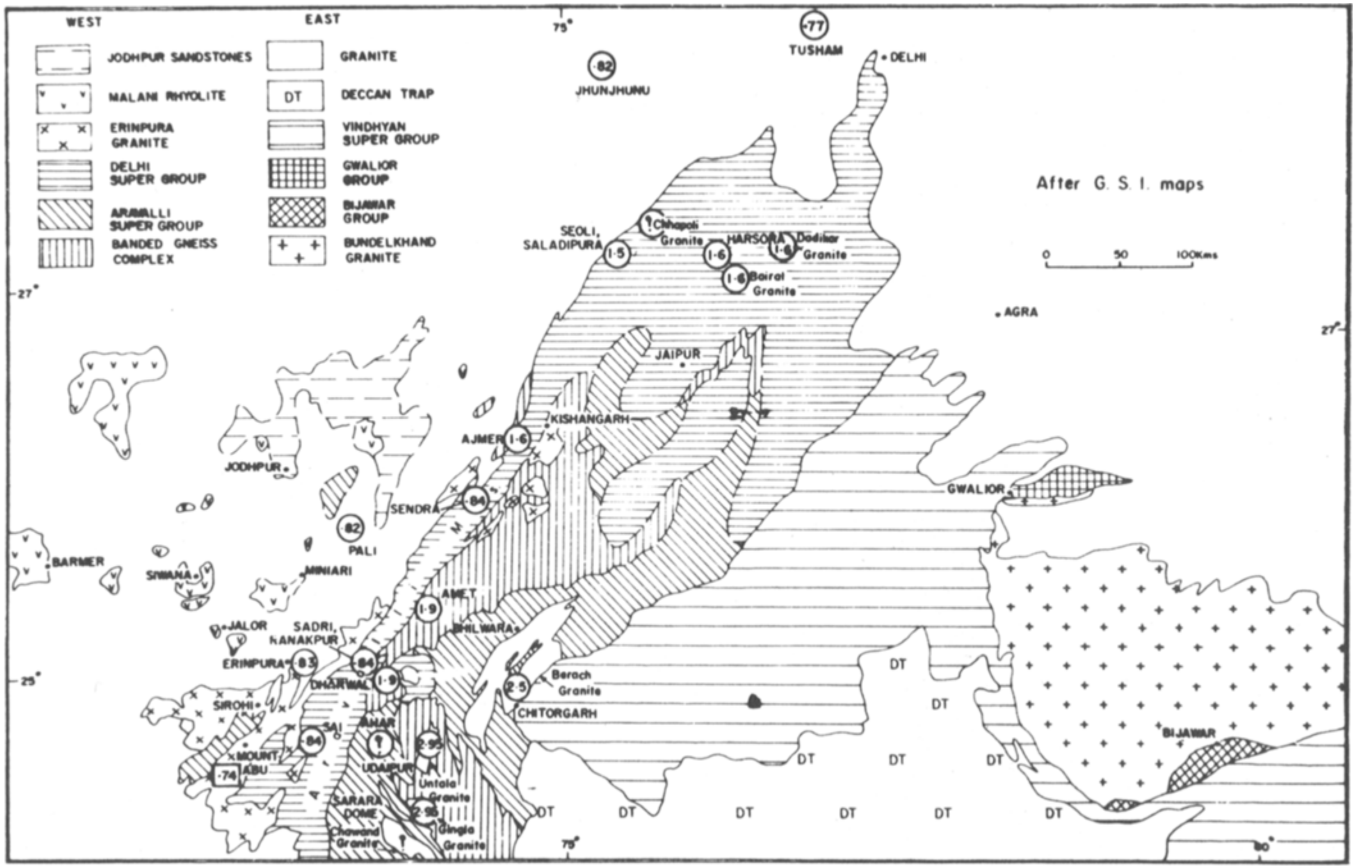

Figure 1. Simplified geological map of Rajasthan and Bundelkhand. The figures within the circles are Rb-Sr whole-rock isochron ages (in billion years) mostly from our work, while those in rectangles are ages from the literature cited in the text.

(Beckinsale *et al* 1980; Basu *et al* 1981). The Berach Granite considered to be the igneous basement in Rajasthan by Heron was dated at about 2·5 b.y. (Crawford 1970). A very old lead isochron age of 3·5 b.y. for the detrital zircons from the Aravalli schists (Vinogradev *et al* 1964) leaves the question of their provenance open. The first direct evidence for ancient crustal remnants comes from the Rb/Sr whole rock isochron age of 2·95 b.y. for the two bodies of granite around Untala and Gingla in the BCG II east of Udaipur (Choudhary *et al* 1982). Since these granites are believed to be late intrusives (Gupta 1934) the host gneisses and amphibolites must be even older. Preliminary Sm/Nd dating of the host gneisses and amphibolites indicates a middle Archean age of 3·5 b.y. (Macdougall *et al* 1983). Though none of the few ages reported from the BGC I to the north is as old, the sampling of this terrain has not been comprehensive enough to rule out the presence of Archaean crust in this region also. The Archaean age of the Untala Granite within the BGC II shows that this high grade gneissic terrain is similar to the well documented Archaean high grade complexes elsewhere in the world. No authentic type 'greenstone belt' has yet been reported from any of the BGC terrains. In view of their crucial importance to the earliest crustal history of the Indian lithosphere, the BGC of Rajasthan and their possible equivalents in Gujarat warrant detailed studies.

The Aravalli Supergroup is now considered to be an early Proterozoic mobile belt. It is very important to the study of the Indian lithosphere as it may record the distinct changes in the tectonic style and structure from the Archaean era and the first development of Cordilleran-type geosynclines with the onset of plate movements comparable to the more recent analogs, documented in other Proterozoic belts (Windley 1973). It consists largely of low-grade deformed sediments and volcanics. The presence of abundant stromatolites and phosphorite in the Udaipur region indicates a shallow shelf environment (Banerji 1971). Roy and Paliwal (1981) described these rocks as miogeosynclinal deposits and hinted that the depositional basins along the rifted continental margin off the east coast of North America (Dickinson 1971) may be envisioned as modern analogues of the Aravalli-type depositional basin. Sen (1981) has proposed that the eastern Aravalli belt (Bhilwara belt) had its origin in a marginal sea with very little development of an oceanic crust, while the western limb through Udaipur is an island arc in an open sea bordering a BGC microcontinent.

Despite its strategic importance in the development of the Indian lithosphere, the Aravalli Supergroup is geochronologically the least known. The imprecise age of about 1·5 b.y. (Crawford 1970) for the Aravalli volcanics is unlikely to be their primary age in view of the demonstrated ease of metamorphic updating of fine grained rocks. The Ahar River Granite believed to be intrusive in the Aravalli rocks (Heron 1953) shows a wide open system behaviour in the isochron plot precluding a reliable age estimate (Choudhary *et al* 1982). Since the Aravalli metasediments around Udaipur rest uncomformably on the BGC with components as old as 2·95 b.y., they can be much older than 2·5 b.y., a strict upper limit suggested earlier by Crawford (1970). Sm/Nd dating of the basal volcanics in the Aravalli sequence can resolve the problem of the age of the Aravalli Supergroup.

Recent geochronological data (Choudhary *et al* 1982) on the various granites in the original Delhi Supergroup of Heron show two distinct age provinces with very little overlap, the older between 1700 and 1500 m.y. in the Alwar and Khetri sectors in north eastern Rajasthan and the younger between 850 and 750 m.y. along the central axis of the range south of Ajmer. This younger magmatism has not only left its thermal overprint on the older Alwar-Khetri rocks but is also nearly synchronous with that related to Malani Igneous Suite in the trans-Aravalli region. This suggests that the Delhi Supergroup of Heron may be comprised of two major metasedimentary sequences with independent magmatic histories at the two periods stated above. Presence of two widely different generations of metasedimentary rock units within the Delhi Supergroup is contrary to the traditional belief, but has recently been proposed by Sen (1981) on independent grounds. He divides the Delhi Supergroup essentially into four separate mobile belts based on distinct tectonic styles and lithologies with the inner pair and outer pair of belts separated widely in time and by a flysch-melange suture zone. The northern extensions of the two innermost zones are called the Khetri and Jaipur linear belts, respectively, while the outermost pair which runs across the entire Rajasthan is called the Pindwara-Ajmer and Sirohi-Ras fold belts, respectively. According to Sen's model, the older northern Aravalli granites belong to the inner pair of zones east of the palaeosuture while the younger granites along and off the central axis belong to the outer zones west of the lineament. Since crustal and age provinces normally coincide, the bimodal age distribution is consistent with but does not necessarily support the plate-tectonic reconstruction of Sen (1981).

No significant occurrence of stromatalites or phosphorite has been found in the Delhi sequence, unlike the Aravalli rocks. This may have an important bearing on the contrasting characteristics in the mode of formation of the Aravalli and the Delhi mobile belts. Also no type ophiolites have been found along the flysch-melange suture zone by Sen (1981). The trans-Aravalli region which has never been explicitly related to the Delhi Supergroup has scattered outcrops of extrusives and intrusives over an extensive area covering Kirana Hills, Tusham, Jhunjhunu, Pali with ages in a narrow time band of 900–700 m.y. (Crawford 1969; Choudhary *et al* 1982; Kochhar 1983). A number of NE-SW trending deep crustal dislocations have been recognised in this region, and the intrusions of alkaline complexes are located close to some of these lineaments (Narayan Das *et al* 1978). All these features suggest that the trans-Aravalli belt may be an arrested rift system and it did not reach the continental drift-ocean floor spreading stage as it may be floored by reactivated sialic basement. The rift valley fault zones presumably were controlled by earlier Precambrian fracture systems, such as known in the region. These major tectonic lineaments acted as guidelines for the formation of graben structures which, in turn, controlled the deposition of continental sandstones (Trans-Aravalli Vindhyan) and basic to trachytic lavas and the intrusion of the late alkaline complexes. Occurrence of igneous intrusions and extrusions with a large spread of ages beginning around 800 m.y. may be due to sporadic activation of the tectonic lineaments until the early Tertiary. Such a vertical mass transport along intracontinental linear rifted zones has recently been proposed specifically for the Tusham igneous complex in Hissar and Malani igneous suite, respectively (Kochhar 1983; Narayan Das *et al* 1978). Sychanthavong and Desai (1977), on the other hand, have proposed that the Delhi sediments were deposited in geosynclinal troughs bordering the Aravalli-BGC protocontinent which subsequently underwent orogeny as a result of subduction of the oceanic plate below the continental margin. The time scales they propose for this orogeny are too long to be reconciled with the rate of Phanerozoic plate movements. According to their model, the Aravalli Range should resemble the present-day continental margin mountain belts and be associated with large linear belts of basic rocks on the ocean side.

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