

Hotspot Magmatism: Evolution of Siwana Granites, Barmer District, Rajasthan

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ABSTRACT

Large amounts of highly heat-generating granites with significant concentrations of radioactive elements are found in Rajasthan, India's Siwana Ring Complex, which is part of the Malani Igneous Suit. The heat produced by these plutons ranges from 4 to 41 w/m³. Due to extensive circulation within these granites, the thermal waters erupting through them are chloride-rich. Such granites could be used in upcoming EGS projects in India and worldwide.

Keywords- *Heat generating granites, Siwana ring complex, EGS Projects, etc*

I. INTRODUCTION

Granite is an intrusive igneous rock with a coarse grain made primarily of quartz, alkali feldspar, and plagioclase. It is results from magma that slowly cools and solidifies below and contains a lot of silica and alkali metal oxides. It is frequently found in igneous intrusions in the Earth's continental crust. They come in a variety of sizes, from dikes that are only a few centimetres across to batholiths that are exposed over a vast area.

Neoproterozoic felsic magmatism in western India (Rajasthan) is represented by a large felsic igneous suit of rocks known as the Malani Igneous Suit (MIS) that spread over an area of 55000 km² and is the largest felsic magmatic event in the world. The suits of rocks are distributed around Tosham, Jhunjhunu, Siwana, Jalore, Barmer, Pali, Jaisalmer in Hariyana and Rajasthan. The rock types include granites and its volcanic equivalents such as rhyolites, trachytes and rhyodacites. All these rocks are characterized by high content of radioactive elements. As a consequence, the entire region registered high heat flow values due to the heat generated by the decay of the radioactive U, Th and K. We describe here the geology, structure and the heat generation capacity of the rocks of granitic composition of Siwana ring complex.

The average chemical composition of granite, by weight percent, based on 2485 analyses:

SiO₂ 72.04% (silica), Al₂O₃ 14.42% (alumina), K₂O 4.12%, Na₂O 3.69%, CaO 1.82%, FeO 1.68%, Fe₂O₃ 1.22%, MgO 0.71%, TiO₂ 0.30%, P₂O₅ 0.12%, MnO 0.05%

SIWANA RING COMPLEX

The Siwana Ring Complex (SRC) is the most spectacular feature in Thar Desert of Rajasthan that can be seen from Landsat imagery and Google earth map. SRC occupies an area of 800 sq. km is located in Barmer district of Rajasthan and is located 120 km SW of Jodhpur.

This structure appears to have been formed due to Caldera subsidence and intrusion of radial dikes around intrusive granite. However, presence of stishovite in the soils round the ring complex invoked a meteoritic impact for the origin of this ring complex while Pascoe suggested that the circular Siwana structure could be the root of a volcano. The rock types in the ring complex include rhyolite, granite, trachyte, basalt, gabbro and dolerite in the decreasing order of abundance. The contact between the rhyolites and the granites is seen along the inner periphery while the contact between these two units along the outer periphery is seen only at Mokalsar, Indrana, Ludara and Mawri. Nearly forty five flows are recorded between the periphery of the complex and the central axis of the projected caldera. The felsic rocks exhibit flow structure, while basalt displays vesicular and amygdular structure. Columnar jointing is observed occasionally. The granite is coarse grained and occurs in pink and grey colours. The alkali feldspars in the granites are altered and give cloudy appearance. The grain size varies considerable and is not uniform. In thin sections, a hypidiomorphic granophyric texture is very commonly seen. The presence of sanidine and bipiramidal quartz indicates a high temperature origin for the granites in the complex. The granites around the complex rise to 925 m above the ground and a large part of the granite mass is covered by alluvium.

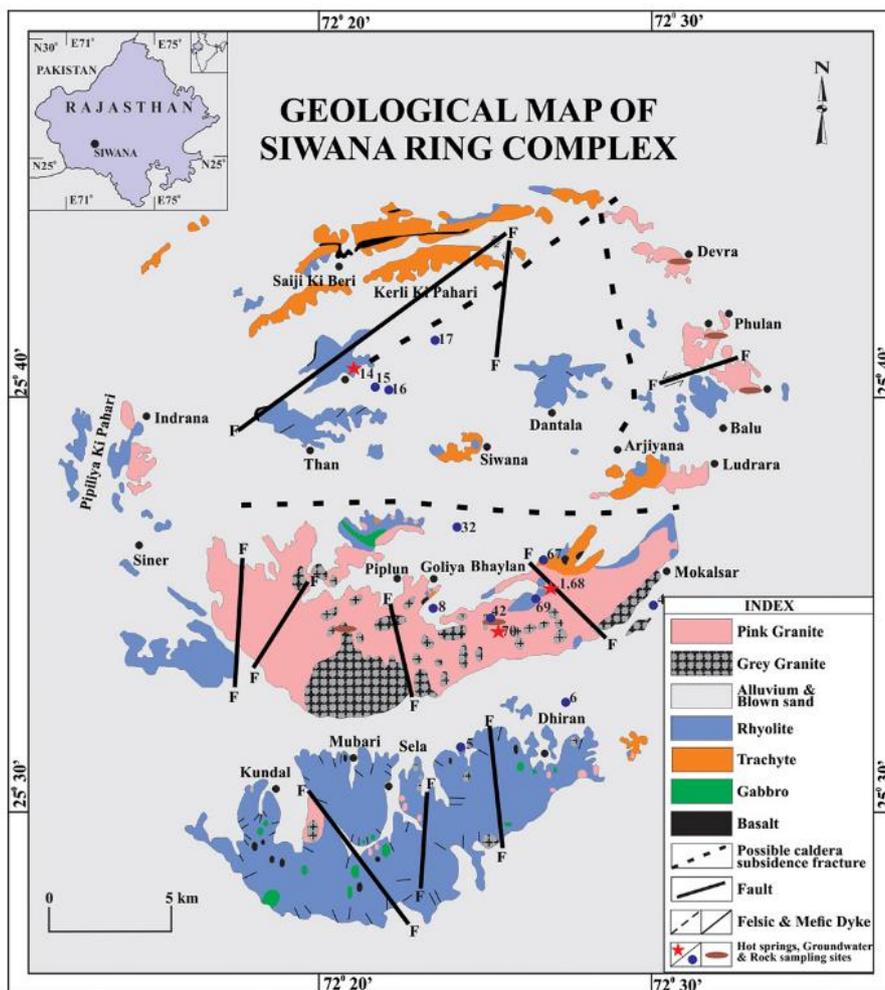


Figure: The Siwana Ring Complex. Location of the thermal springs are shown in Red star modified after many researchers.

THE STUDY OF RADIOACTIVITY OF THE GRANITES

The characteristic feature of the granites of Siwana and other plutons within the Malani Igneous Complex is the abundance of radioactive elements like uranium, thorium and potassium. The concentration of these elements in the granites and the radioactive heat production (RHP) by these granites of Siwana are shown in Table 1. These values are much above the average values of granites $5\mu\text{W}/\text{m}^3$ of granites. This heat apparently heats the circulating fluids within these rocks giving rise to the thermal springs located within these granites that is also given in figures.

THERMAL SPRINGS

The surface temperature of the thermal springs issuing through these granites varies from 30 to 40 °C. In fact certain bore well drilled for domestic use also yield water with this temperature. It has been reported that these thermal springs are mixing with the local groundwater at shallow levels before emerging to the surface. High chloride content in the thermal springs 1200 to 2800 ppm indicate prolonged interaction with the granites there by getting enriched in chloride due to dissolution of biotite and hornblende which are the main source of chloride in rocks of granitic composition. In fact many thermal systems that circulate within the granite have high chloride content due to long residence time and is the heat source being radiogenic. These investigations clearly demonstrate that natural geothermal systems in granites are common in several provinces and detailed geological, geophysical and geochemical investigations on such provinces will help in enhancing our understanding about EGS systems.

Table: Radioactive element content in Siwana granites (Data represented here is cited 1-5 from Singh et al., 2014; and 6-9: from Singh and Vallinayagam 2013)

S No	U (ppm)	Th (ppm)	K (wt%)	Th/U	HP (μWm^{-3})	Heat Flow (mWm^{-2})
1	17.8	165	5.32	9.27	16.5	204.8
2	19.6	102	4.98	5.2	12.6	165.6
3	11.8	44.7	4.77	3.79	6.6	105.7
4	6.88	31.3	4.86	4.55	4.4	83.9
5	7.9	28.2	3.47	3.57	4.3	83.1
6	46.71	152.97	4.1	3.27	23.56	269.6
7	86.11	148.1	4.05	1.27	33.52	367.5
8	24.7	105.44	3.95	4.27	14.39	180.1
9	98.71	216.8	3.5	2.2	41.68	446.9

II. RESULTS, DISCUSSION AND CONCLUSIONS

The granites exposed in the Siwana Ring Complex of Rajasthan, like other granites exposed in the Indian subcontinent, contain high content of radioactive elements and thus generate heat greater than generated by normal granites. The radioactive heat production by these granites is about 4 to 41 $\mu\text{W}/\text{m}^3$. The wet geothermal systems located along major rift zones (Cambay, Narmada Rift, Godavari rift) are driven by such high heat generating granites. In certain sites, like Bakreswar, West Bengal and Tattapani in the Narmada rift zone, the thermal gases contain high helium content varying from 1 to 2 % v/v indicating the thermal reservoir within such granites. The reservoir temperatures estimated using cation geothermometers in the thermal waters circulating in such granites vary from 160 to 265 °C with reservoir depths varying from 2 to 3 km. The total surface exposure of such high heat generating granites in India is 150 000 sq.km while the area occupied by MIS felsic rocks is 55000 sq km and that of SRC is 800 sq km. All the above study is purely based on the literature review.

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