Occurrence of stishovite in the Precambrian Siwana Volcanic Province, Western Rajasthan, India

Minerals such as coesite, stishovite and meshkelenite, formed due to meteoritic or asteroid impact, signify and preserve events of unusual high temperature and pressure[1]. Here we report the occurrence of stishovite in magnetic particles found in Mokalsar–Siwana way of the Siwana volcanic province in western Rajasthan, India (Figure 1). Such magnetic spherules, with 57% of magnetite and 37% haematite and with insignificant rare earth element (REE) content have been reported recently from a wide variety of geological formations and Recent Alluvium[2–4].

In order to understand their geochemistry (trace elements and REE), genesis and distribution of these magnetic particles, we independently collected about 24 samples of magnetic particles distributed in the recent soil of western Rajasthan. Out of 24 samples, two samples, 5a and 5b, collected within a distance of 100 m, one from the rhyolite hill on the Siwana–Mokalsar way (25°41′21″N: 72°33′729″E; altitude 161 m) and the other from Kraser, near Rakhi (25°41′024″N: 72°3′738″E; altitude 141 m) registered anomalous REE content relative to the rest of the samples (Table 1). The remaining 22 samples have similar chemistry and hence chemical analyses of only four representative samples are given in Table 1. X-ray diffraction (Rigaku d-max wide angle XRD unit) pattern on samples 1 (Agolai) and 5a (Siwana–Mokalsar way) was taken (Figures 2 and 3). JCPDS data file was used to identify the minerals. As evident from X-ray diffractogram, stishovite is present in sample 5a that has anomalous REE content whereas only magnetite and haematite are present in other samples with low REE content. To confirm the presence of stishovite in sample 5a, ^{29}Si MAS NMR spectra on the acid treated sample was undertaken at the Sophisticated Analytical Instrumental Facility (SAIF) at IIT Bombay. The NMR spectrum is shown in Figure 4*a*. Enlarged part of the spectra (–150 to –200) is shown in Figure 4*b*. Characteristic quadruplets at δ, –95.985, –159.416, –169.116 and triplets at –195.813 confirm the presence of tetrahedrally coordinated and octahedrally coordinated silicon signals in the sample. NMR peak at –195.813 confirms the presence of

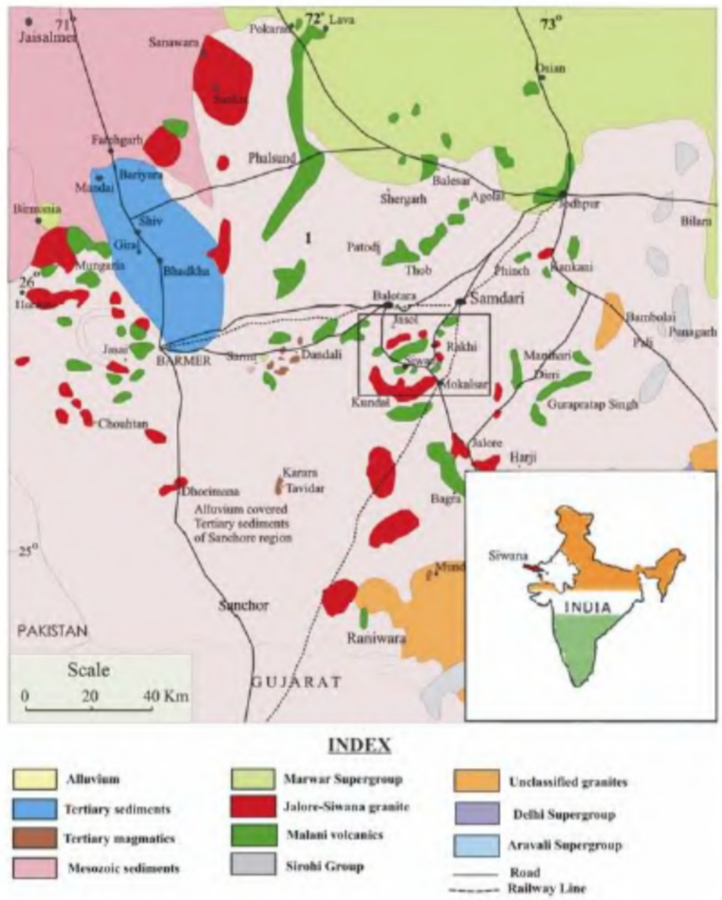

Figure 1. Location and geological map of the study area (modified after refs 12 and 13).

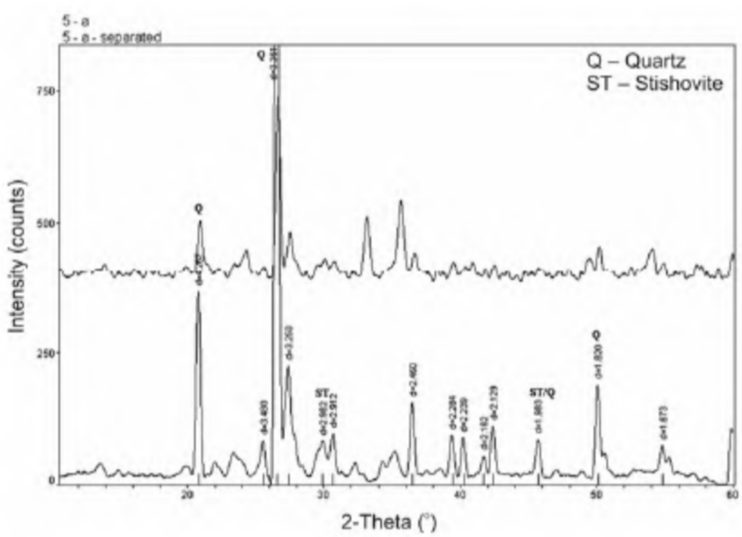

Figure 2. X-ray diffraction pattern for sample 5a. 5a-sp shows XRD-pattern of the same sample after acid treatment to remove iron.

Table 1. Trace elements and REE data on magnetic particles from some localities of Western Rajasthan

	1 (Agolai)	2 (Mandli)	3 (Bavli)	4 (NS Rakhi)	5a (Si-Mo way)	5b (Kraser Rakhi)
Sc	4	3	5	2	2	4
V	1728	1792	1594	581	137	908
Cr	149	127	168	56	4	106
Co	58	56	56	24	6	45
Ni	57	52	54	18	11	56
Cu	57	38	50	35	31	153
Zn	486	505	503	457	755	986
Ga	21	22	19	7	38	25
Rb	7	7	5	8	61	17
Sr	275	56	57	48	62	44
Y	12	11	13	53	1411	369
Zr	61	36	42	377	2664	740
Nb	18	10	13	37	294	109
Cs	17	19	14	19	56	53
Ba	1638	337	476	342	268	256
La	28	26	24	35	158	893
Ce	37	30	36	66	5372	1552
Pr	4	4	4	6	172	87
Nd	25	23	20	38	1007	488
Sm	4	4	4	8	269	103
Eu	0.8	0.5	0.6	1.2	32	10
Gd	3	3	3	8	267	91
Tb	0.3	0.3	0.4	1.2	37	11
Dy	2.4	2.6	2.8	10	291	82
Ho	0.4	0.4	0.5	2.1	53	14
Er	1.2	1.1	1.2	5.8	115	33
Tm	0.2	0.2	0.2	1.5	21	6
Yb	1.4	1.2	1.4	10	104	30
Lu	0.2	0.1	0.1	2	14	4
Hf	4	2	3	25	134	39
Ta	4	1	2	1	26	14
Th	5	7	8	5	31	8
U	1	1	1	1	10	3

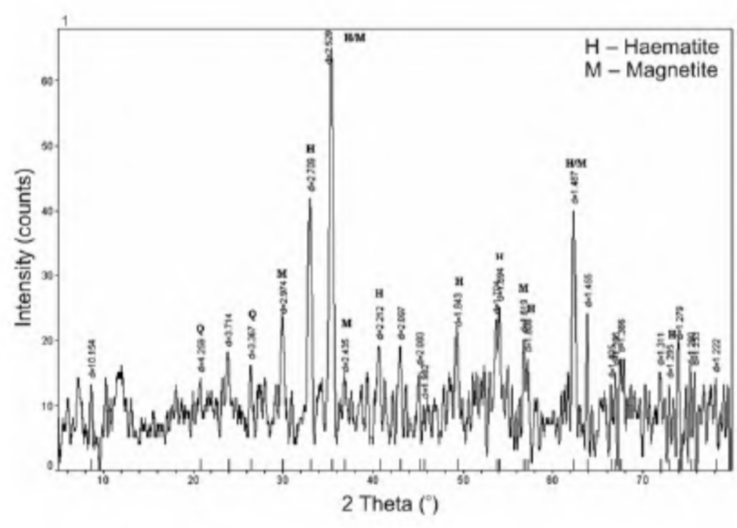

Figure 3. X-ray diffraction pattern of sample 1 (Agolai).

stishovite. The current NMR signature of sample 5a closely resembles the NMR peaks reported earlier for stishovite from New Mexico[5].

Quartz, a common mineral in the earth crust is silica (SiO_2) polymorph with silicon in tetrahedral coordination with oxygen. At 3.5 GPa pressure, quartz converts to coesite, a dense, tetrahedral coordinated monoclinic polymorph. At pressures greater than 8.5 GPa, stishovite is formed, as a denser and tetragonal poly-

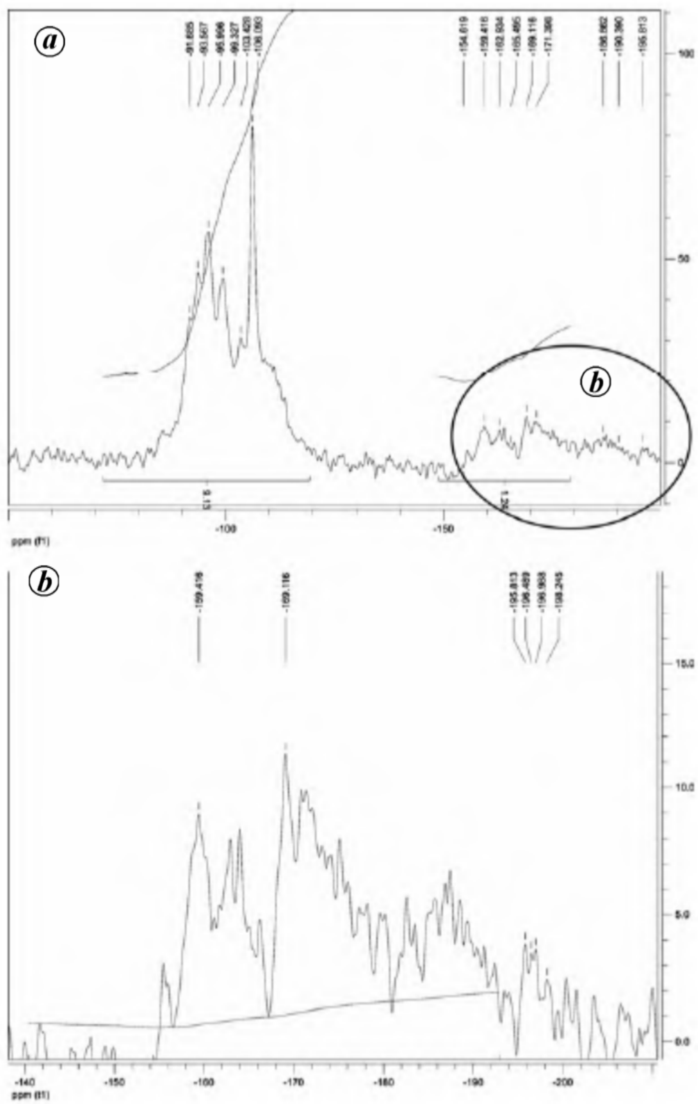

Figure 4. ***a***, MAS NMR spectra of sample 5a and ***b***, enlarged spectra.

morph[6]. Stishovite is metastable at atmospheric pressure and moderate temperature. It can be found in natural samples from known or suspected meteoroidal impact sites and is considered diagnostic of impact-induced shock metamorphism[7].

Stishovite has not been reported till date from any chronostratigraphic sequences or areas of western Rajasthan although it has been reported in meteoritic craters from other parts of the world[8,9]. In the first site, we find that Siwana ring structure is the only structure in western Rajasthan which is geologically unusual. There are a number of geological features which makes Siwana ring structure unique, e.g. geographic location, geological relations in the vicinity of the suspected structure, distinctive shape, surface sculptures, heterogeneity[10–15], chemical affinity with spherules[2] and the occurrence of stishovite-bearing magnetic particles. Now, with the discovery of spherules[2,3] and the presence of stishovite from western Rajasthan goads us to probe the various anomalies found in the ring structures including the possibility of the presence of some more impact features in this region which are yet to be explored.

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R. P. TRIPATHI[1]
S. C. MATHUR[2]
SONAL MATHUR[2]
G. TRUPTI[3]
D. CHANDRASHEKHARAM[3,*]

[1]*Department of Physics, and*
[2]*Department of Geology,*
J. N. Vyas University,
Jodhpur 342 001, India
[3]*Department of Earth Sciences,*
Indian Institute of Technology Bombay,
Mumbai 400 076, India
**For correspondence.*
e-mail: dchandra@iitb.ac.in