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Provenance, Petrofacies, Tectonic Setting and Diagenesis of Sawa Sandstones, Lower Vindhyan, in and around Rithola Village, Chittaurgarh, Southeastern Rajasthan, India

Jyoti Mathur, Abdullah Khan, Meradul Islam

***Abstract*— Sawa Sandstone Formation (~60m) representing clastic assemblage of Lower Vindhyan Supergroup of southeastern Rajasthan overlies Bhagwanpura Limestone Formation with sharp, non-depositional contact and crops out as narrow linear ridges of sandstone trending north-south along regional strike with regional dip towards east. The Sawa Sandstones in and around Rithola village, southwest of Chittaurgarh were studied in order to understand provenance, tectonic setting and diagenetic history. The sandstones consist of various types of quartz, feldspar, rock fragments and micas which are medium to coarse grained and subangular, subrounded to rounded, predominantly moderately well sorted to moderately sorted, derived mainly from Banded Gneissic Complex and preceding Vindhyan Succession located to the west of study area. Petrofacies study reveals that the Sawa sediments were derived mainly from craton interior and continental block orogen provenance. The chemically precipitated cements include silica, iron oxide, calcite in order of abundance.**

***Index Terms*— Sawa Sandstone Formation, Petrofacies, Tectonic Setting, Diagenesis, Southeastern Rajasthan**.

I. Introduction

The Meso-Neoproterozoic Vindhyan Supergroup is about ~4 km thick. It is one of the largest and thickest Proterozoic sedimentary basins of the world [1]. It covers about 1,00,000 km2 area, of which 60,000 km2 are exposed and about 40,000 km2 area are concealed below the Indo-Gangetic Plain and in the south– eastern part by Deccan Continental Flood Basalt (DCFB). The western margin of this sickle shaped basin is marked by presence of lower Vindhyan succession comprising sandstone, shale, limestone, conglomerate and mafic volcanic flows at the base. The sequence commences with basaltic-andesitic volcanic flows and volcano clastics (Khairmala Andesite Formation) which rest unconformably on early Precambrian granite and Banded Gneissic Complex (BGC). As a whole, the sequence is predominantly unmetamorphosed and mildly deformed.

The present study deals mainly with mineralogical compositions, texture and diagenetic history of Sawa Sandstones. An attempt has been made to interpret the provenance and tectonic setting on the basis of the detrital mineral compositions and petrofacies analysis.

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II. Geological Setting

An unmetamorphosed sequence of Meso-Neoproterozoic sedimentary rocks occupies the northern fringe of peninsular India (Fig. 1). These sedimentary rocks surround the Bundelkhand Granite and are known in Indian stratigraphy as the Vindhyan Supergroup which is subdivided into the Semri, Kaimur, Rewa and Bhander Groups.

The detailed geology of the area has been worked out by Prasad (1984). The stratigraphic succession of the Lower Vindhyan Group of southeastern Rajasthan is summarized in Table 1 [2-3]. The Sawa Formation comprises mainly sandstones with conglomerate. The sandstone assemblage which overlies Bhagwanpura Limestone Formation crops out as narrow ridges of sandstone (Fig. 2).

Table 1: Lithostratigraphic Succession of the Vindhyan Sequence, Southeastern, Rajasthan(after Prasad, 1984; Casshyap et al., 2001)

Group	Formation	Lithology	Thickness (m)
Upper Vindhyan Shale	Kaimur	Sandstone, Conglomerate,	20-70
~~Unconformity~~~~~~~~~~~~~~~			
L	Suket	Shale	120
O	Nimbhara	Limestone	100-150
W	Bari	Shale	45
E	Jiran	Sandstone	30-60
R	Binota	Shale	250
	Palri	Shale	30-60
V	Sawa	Sandstone	30-60
I	Bhagwanpura	Limestone	30-50
N	Khardeola	Shale and	
D		Sandstone	70-200
H	Khairmala	Basaltic-	
Y		andesitic	
A		Volcanic flows	
N		and volcano-	
		Clastics	40-100
~~Unconformity~~~~~~~~~~~~~~~			
Banded Gneissic Complex (BGC)			

III. METHODOLOGY

The sampling of sandstones were carried out at regular intervals and keeping in view, the physical variation between different units. Twenty five representative fresh outcrops samples were selected for petrographic study. Petrofacies and textural analysis and percentage of detrital and authigenic components were calculated by point counting using the Gazzi-Dickinson method taking into account 300 grains were counted for each thin section [4]. For petrofacies analysis, the detrital mode were recalculated to 100 percent by summing up of Qt, Qm, F, L and Lt following the Dickinson's (1985) method [5]. In the ternary diagram, constructed for delineating the tectonic setting of the provenance by Dickinson (1985), the polycrystalline quartz was placed at the Lt pole in the Qm-F-Lt plot and at Qt pole in the Qt-F-L diagram in (Fig.4a, b). Cherts are of sedimentary origin (Plate 1(c)) and therefore placed at the rock fragment pole of the plots. The F pole comprises all types of feldspar grains including those from a granitic source.

The source rock composition, provenance and tectonic setting of the Sawa Sandstones were deduced using the modal analysis data. The modal data were plotted in the diagrams suggested by Dickinson (1985).

IV. DETRITAL MINERAL COMPOSITION

The mineralogical study revealed that the framework constituents of the studied sandstones are mainly composed of quartz followed by feldspar, rock fragments and mica. The average composition of detrital mineral in quartz (95%), feldspar (4%), mica and rock fragments (1%). The same was plotted on triangular diagram as proposed by Folk (1980) in order to classify and designate the sandstone [6]. It shows that the sandstone is predominantly quartzarenite type (Fig. 3). Different varieties of quartz e.g. common quartz, recrystallised metamorphic quartz and stretched metamorphic quartz along with varieties of feldspar were recognized.

V. PETROFACIES AND TECTONO- PROVENANCE

Petrofacies implies detrital sandstone and tectono-provenance significance [7]. The relationship between plate tectonics and sandstone composition has been subject of intensive research and the discussion over the last four decades or so. Many studies have pointed to an intimate relationship between detrital sand compositions and tectonic setting [5,8-20].

The proportions of detrital framework grains plotted on triangular diagram provides effective discrimination of variety of plate tectonic setting and have been used as a powerful tool for determining the origin and tectonic reconstruction of terrigenous deposits [5]. In the present study, the detrital minerals of Sawa Sandstone were studied for interpreting their provenance and tectonic setting with the help of classification scheme of Dickinson (1985). Detrital modes were recalculated 100% as the sum of Qm, Qp, Qt, F, P, K, Lv, Ls, L and Lt (Table 2). These recalculated petrographic

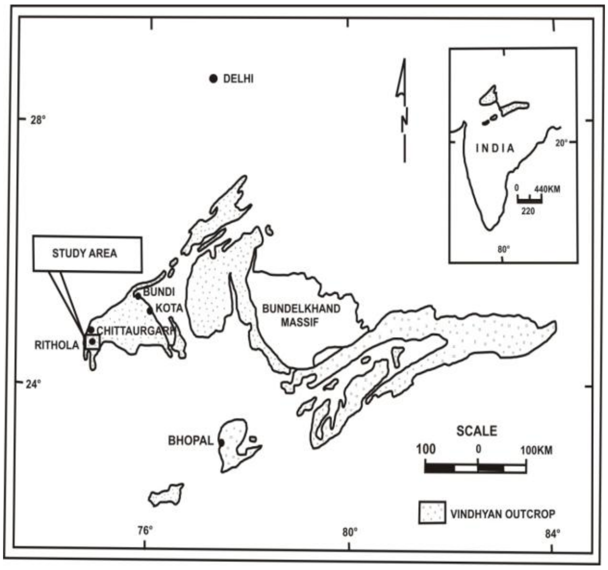


Fig. 1: Geological map of Vindhyan basin showing the study area

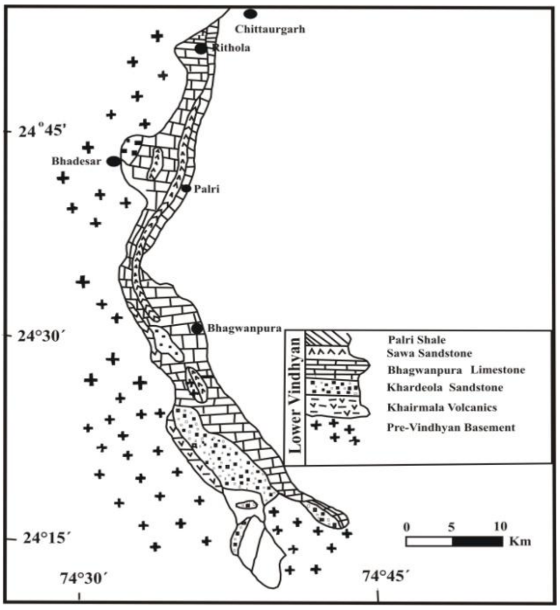


Fig. 2: Geological map showing distribution of Sawa Sandstone and others Sequences

data (Petrofacies) were plotted in four triangular diagrams i.e. Qt-F-L, Qm-F-Lt, Qp-Lv-Ls, Qm-P-K after Dickinson (1985) in order to understand tectonic setting of provenance (Fig.4a,b,c,d).

Both Qt-F-L and Qm-F-Lt diagrams show full grain populations but with different emphasis. In the Qt-F-L diagram, where all quartose grains are plotted together, the emphasis is on grain stability and thus on weathering, provenance, relief and transport mechanism as well as source rock while in Qm-F-Lt plot, where all lithic fragments are grain size of the source rock, because finer grained source rocks yield more lithic fragments in the sand size range. In Qt-F-L diagram, all the sample data fall in the Continental Block Provenance with source on stable craton (Fig.4a).In Qm-F-Lt diagram, where all the sample data fall in the stable craton of Continental Block Provenance (Fig.4b). The Qp-Lv-Ls plot, which is based on rock fragments population, reveals the poly-mineralic component of source region and gives a more

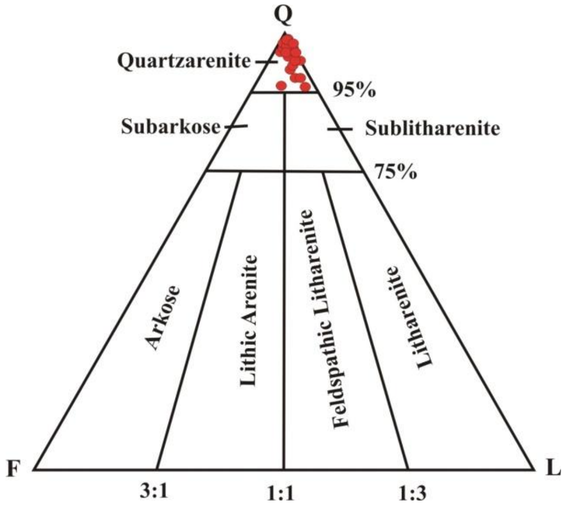


Fig.3: Classification of Sawa Sandstones (after Folk, 1980)

Table 2: Recalculated volume percentage of framework constituents of Sawa Sandstones (based on classification of Dickinson, 1985)

Sample No.	Qt-F-L(%)			Qm-F-Lt(%)			Qp-Lv-Ls(%)			Qm-P-K(%)		
	Qt	F	L	Qm	F	Lt	Qp	Lv	Ls	Qm	P	K
SS-1	97	2	1	92	2	6	83	0	17	98	1	1
SS-2	97	3	0	94	3	3	100	0	0	97	1	2
SS-3	98	1	1	91	1	8	88	0	12	99	0	1
SS-4	98	2	0	88	2	10	100	0	0	98	0	2
SS-5	97	2	1	90	2	8	88	0	12	98	1	1
SS-6	90	8	2	88	8	4	67	0	33	92	5	3
SS-7	93	5	2	89	5	6	80	0	20	95	1	4
SS-8	93	5	2	90	5	5	75	0	25	95	2	3
SS-9	99	1	0	96	1	3	100	0	0	100	0	0
SS-10	93	5	2	91	5	4	100	0	0	95	3	2
SS-11	97	2	1	92	2	6	83	0	17	98	1	1
SS-12	98	1	1	96	1	3	67	0	33	99	1	0
SS-13	93	5	2	90	5	5	75	0	25	95	2	3
SS-14	96	4	0	95	4	1	100	0	0	96	2	2
SS-15	95	3	2	93	3	4	67	0	33	97	2	1
SS-16	97	3	0	93	3	4	100	0	0	97	2	1
SS-17	88	10	2	81	10	9	87	1	3	89	1	10
SS-18	96	1	3	82	1	17	93	0	7	99	1	0
SS-19	91	8	1	78	8	14	92	0	8	90	4	6
SS-20	97	3	0	95	3	2	100	0	0	97	1	2
SS-21	91	7	2	88	8	4	67	0	33	94	4	2
SS-22	97	1	2	95	1	4	67	0	33	99	0	1
SS-23	98	1	1	97	1	2	100	0	0	99	0	1
SS-24	97	2	1	95	2	3	67	0	33	98	1	1
SS-25	94	6	0	92	6	2	100	0	0	94	4	2
Average	95	4	1	91	4	5	86	0	14	97	1	2

resolved picture about tectonic elements. The studied samples fall in the field of rifted continental margin provenance (Fig.4c). The Qm-P-K plot of the data shows that all the sediment contribution is from continental block basement uplift provenance reflecting maturity of the sediments (Fig.4d).

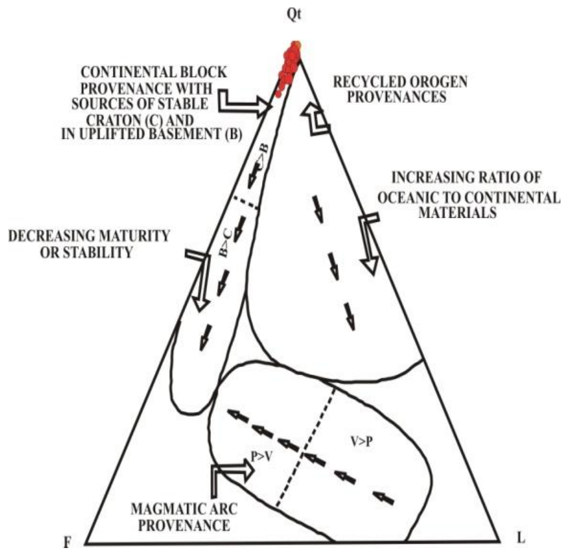
VI. Diagenesis

Diagenetic signatures observed in Sawa Sandstone include different stages of compaction, cementation change in crystal boundaries, chertification and neomorphism which evolved during stages of diagenesis.

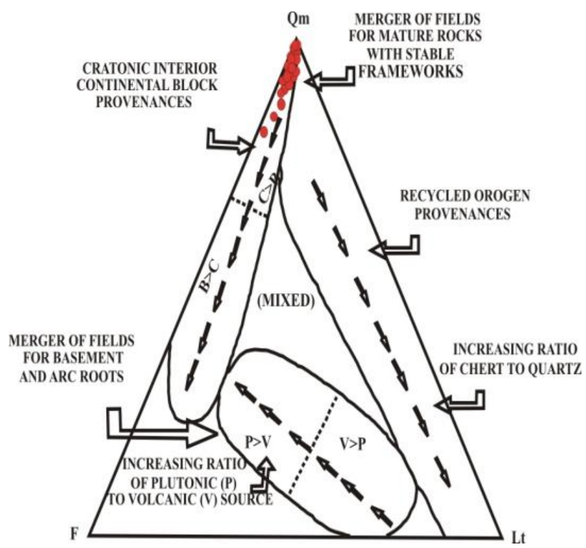
A. Compaction

The grain to grain and overgrowth contacts were analyzed to workout pre and syncementation compaction on one hand and point cementation on the other. It seems that the compation started before any cementation event resulting into high point and long grain to grain contacts and continued during silica cementation. The post silica cementation compaction is evidenced by interpretative contacts having concavo-convex contact.

The nature of point contacts and contact index are helpful in understanding the aggregate packing of the rocks. In our study, the closely packed sandstones exhibit five types of grain contacts which include floating (F), point (P), long (L), concavo-convex (C) and suture (S) contacts [21]. In loosely packed sandstone, some grains may not make any contact with other grains, such grains are referred to as floating grains (F). The observed number of various types of grain contacts in samples is given in Table 3 and bar diagram constructed on the basis of grain contact data is shown in Fig. 5.



(a)



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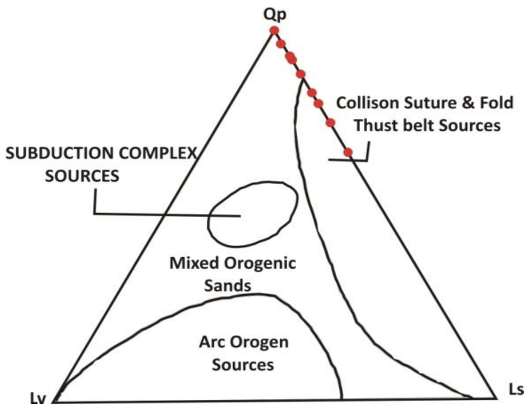
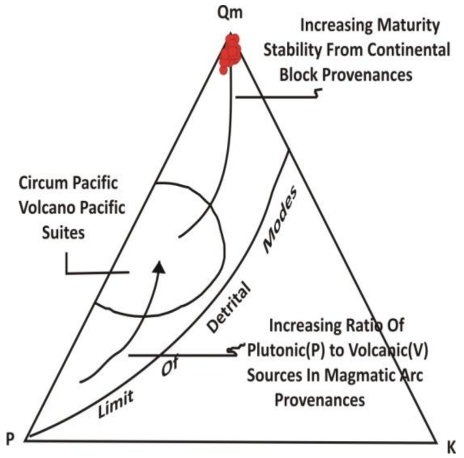


(c)



(d)

Fig. 4: (a) Qt-F-L diagram of Sawa Sandstones given by after Dickinson, 1985 (b) Qm-F-Lt diagram of Sawa Sandstones given by after Dickinson, 1985 (c) Qp-Lv-Ls diagram of Sawa Sandstones given by after Dickinson, 1985 (d) Qm-P-K diagram of Sawa Sandstones given by after Dickinson, 1985.

The average percentage of different types of contacts in the studied Sawa Sandstone is as follows; floating (14%), point (17%), long (52%), suture (10%) concavo-convex (7%) contacts (Table 3). In Sawa Sandstone, the dominance of point and long contacts (Plate 1d), together averaging at 69% ,suggests that the detrital grains did not suffer much pressure solution, as a result of either shallow burial or early cementation.

B. Cementation

Three types of cements i.e. silica, iron and calcite have been identified under microscope. Silica occurs as the overgrowth while clay occurs as matrix.

- *Silica Cement*

The percentage of silica cement ranges from 3% to 20%, averaging to about 12% (Table 4). In most of the samples, it occurs in the form of quartz overgrowth on detrital grains. Silica overgrowth develops due to precipitation of aqueous solution, in optical continuity with the grains. This silica overgrowth is mainly developed on monocrystalline quartz as compared to polycrystalline quartz. This overgrowth of quartz partially filling the intergranular spaces

Table 3: Packing Data of Sawa Sandstones

Sample No.	Nature of grain contacts around grain poins										Number of contacts per grain												CI
	F		P		L		Cc		S		0		1		2		3		4		>4		
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	
SS-1	4	6	4	6	47	65	7	10	10	14	11	8	25	18	55	40	40	29	5	4	1	1	3
SS-2	9	12	8	10	40	52	9	12	11	14	20	19	35	34	40	38	5	5	3	3	1	1	2
SS-3	10	10	9	9	55	54	12	12	15	15	15	14	20	19	55	51	9	8	7	6	2	2	2
SS-4	4	5	8	10	45	58	10	13	10	13	10	9	35	30	45	39	25	22	1	1	0	0	1
SS-5	9	14	11	17	35	54	7	11	3	5	10	9	30	28	45	42	17	16	3	3	1	1	2
SS-6	7	10	9	13	35	51	7	10	11	16	10	9	50	47	30	28	10	9	5	5	1	1	2
SS-7	2	4	5	10	20	38	15	29	10	19	8	7	28	25	47	42	25	22	5	4	0	0	2
SS-8	4	6	9	13	43	61	10	14	5	7	5	4	20	17	50	43	35	30	5	4	0	0	3
SS-9	3	5	9	16	35	64	5	9	3	5	55	52	35	33	10	10	5	5	0	0	0	0	1
SS-10	3	5	7	12	39	67	6	10	3	5	57	52	40	37	12	11	0	0	0	0	0	0	1
SS-11	2	3	21	30	28	41	8	12	10	14	50	29	70	41	44	26	7	4	0	0	0	0	2
SS-12	4	9	10	22	26	58	1	2	4	9	60	38	47	29	33	21	19	12	1	1	0	0	2
SS-13	26	31	7	8	45	54	1	1	5	6	40	31	55	43	20	16	10	8	4	3	0	0	2
SS-14	5	7	18	25	41	58	3	4	4	6	12	9	35	27	48	38	30	23	2	2	1	1	2
SS-15	21	22	15	16	50	53	2	2	7	7	27	18	36	24	60	41	20	14	5	3	0	0	2
SS-16	8	18	6	14	25	57	0	0	5	11	20	13	50	34	44	30	30	20	5	3	0	0	2
SS-17	20	24	9	11	45	53	0	0	11	13	25	17	65	43	47	31	12	8	2	1	0	0	2
SS-18	10	11	25	28	40	45	3	3	10	11	35	34	50	49	11	11	7	7	0	0	0	0	1
SS-19	20	27	7	9	40	54	2	3	5	7	25	24	65	62	10	10	5	5	0	0	0	0	1
SS-20	25	29	10	12	45	52	1	1	5	6	20	19	45	42	18	17	25	23	0	0	0	0	2
SS-21	10	6	45	29	65	42	15	10	20	13	15	15	45	45	35	35	5	5	1	1	0	0	2
SS-22	25	25	30	29	40	39	2	2	25	5	8	8	45	43	35	34	15	14	1	1	0	0	2
SS-23	30	26	21	18	55	48	3	3	5	4	10	10	35	35	45	45	10	10	1	1	0	0	2
SS-24	21	16	35	27	55	42	7	5	12	9	26	25	40	38	30	29	7	7	1	1	0	0	0
SS-25	25	24	32	31	40	38	2	2	5	5	12	10	45	37	35	28	25	20	4	3	2	2	2
Avg	12	14	15	17	41	52	6	7	9	10	23	19	42	35	36	30	16	13	2	2	0.36	0.36	2

Abbreviation used: F- Floating grain, P- Point contact, L- Long contact, Cc- Concavo-convex contact, S- Sutured contact, CI- Contact Index

- *Iron Oxide Cement*

The percentage of iron cement ranges from 3% to 21%, averaging to about 11% (Table 4). Iron oxide cement occurs in three different forms: first, as a thin coating around the detrital grain boundary; second, as isolated patches and third, as pervasive pore fillings. Some feldspar are in corroded form.

- *Calcite Cement*

The percentage of calcite cement ranges from 0% to 6%, averaging to about 2% (Table 4). It occurs in minor quantity as pachy distribution because it have been formed by alteration of feldspar, mica and clay minerals.

C. Clay Matrix

Clay matrix ranges from, 1 to 6%, averaging to about 3% (Table 4). Scanning Electron Microscope (SEM) study indicate that Kaolinite occurs in dominance (Plate 1e) with small amount of chlorite and smectite.

Table 4: Percentage of cementation and porosity data of Sawa Sanstones

Sample No.	Detrital Grains	Cements			Matrix	Existing Optical Porosity (EOP)	Minus Cement Porosity (MCP)
		Silica	Iron	Calcite			
SS-1	77	12	8	1	1	1	23
SS-2	85	8	3	0	2	2	15
SS-3	81	11	4	2	1	1	19
SS-4	71	13	10	1	3	2	29
SS-5	61	20	11	3	4	1	39
SS-6	72	10	9	5	1	3	28
SS-7	79	9	8	0	2	2	21
SS-8	83	7	6	0	3	1	17
SS-9	84	5	7	0	1	3	16
SS-10	81	6	5	3	2	3	19
SS-11	78	10	3	5	2	2	22
SS-12	62	17	14	0	3	4	38
SS-13	66	11	15	2	4	2	34
SS-14	57	18	16	3	5	1	43
SS-15	60	15	18	2	3	2	40
SS-16	68	9	8	6	6	3	32
SS-17	72	13	10	2	1	2	28
SS-18	79	3	12	1	3	2	21
SS-19	63	14	17	0	5	1	37
SS-20	62	15	16	0	6	1	38
SS-21	53	20	21	2	2	2	47
SS-22	72	12	10	4	1	1	28
SS-23	72	13	9	1	2	3	28
SS-24	67	15	11	4	1	2	33
SS-25	69	13	14	0	3	1	31
Average	71	12	11	2	3	2	29

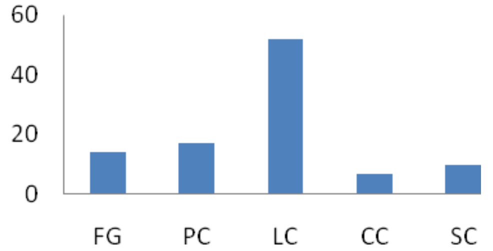


Fig. 5: Bar diagram showing types of contacts for Sawa Sandstone (where FG= Floating grain, PC= Point contact, LC= Long contact, Cc= Concavo-vex contact, SC= Sutured contact)

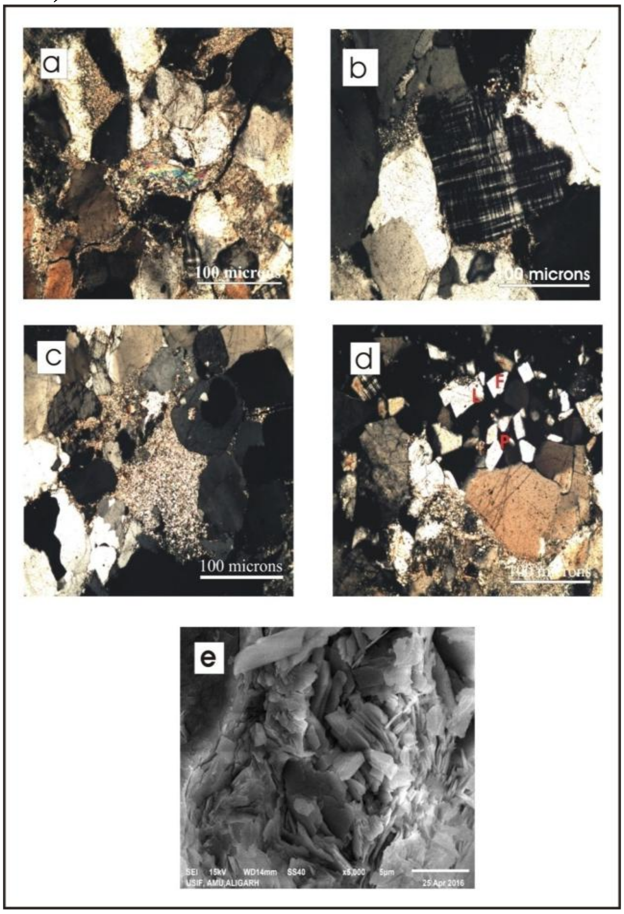


Plate 1: Photomicrograph showing (a) muscovite grain (b) feldspar (microcline) grain in contact with quartz grain (c) Chert (d) Long (L), Point (P) and Floating (F) contact (e) SEM microphotograph showing Kaolinite clay mineral

VII. Conclusion

Sandstones are predominantly quartzarenite type and comprise of several varieties of quartz, feldspar, rock fragments and mica. Sandstones are cemented mainly by silica cement which show very well developed pore filling overgrowths. The iron oxide cement occur in the form of coating around the detrital grains as well as patches, which show replacement corrosion of detrital grains. The nature of grain to grain and overgrowth to overgrowth contacts suggests that the compaction process started just after deposition, before cementation.

The Qt-F-L and Qm-F-Lt diagrams suggest sediment supply from craton interior and continental block provenance. The sediments were deposited in intracratonic rifted basin as evidenced by Qp-Lv-Ls diagram. The Qm-P-K diagram suggests the maturity and stability of source region. The continental block provenance that supplied detritus to the rift was highly weathered. Probably a low relief marked the continental block provenance permitting detritus a long residence time in soil.

The Sawa Sandstones exposed near Rithola Village, southwest of Chittaurgarh represent their derivation from varying source lithology including medium to high grade metamorphosed, plutonic basement which represent granites, granite-gneisses, low and high grade metamorphic supracrustal rocks.

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