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^{57}Fe Mössbauer spectroscopy study of sediments collected from test wells drilled in the Bikaner–Nagaur basin

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ABSTRACT

For the first time, ^{57}Fe Mössbauer spectroscopic investigation of deep subsurface sediments of Bikaner–Nagaur petroliferous basin (containing heavy viscous oil) is reported. In present investigation Mössbauer study was carried out on the samples of wells Lunkha-1 and Pinodha-1 collected from different depth interval. Our results show that Paleocene sedimentary sequence of this basin have appreciable presence of iron in clay, Jurassic sediments are rich in siderite. Majority of the samples from other formation do not show any Mössbauer signal, indicating very meager presence of iron, beyond the detection limit of Mössbauer Spectroscopy. But few of them indicated presence of iron, out of which many samples exhibit presence of hematite, signature of oxidizing condition in sediments.

1. Introduction

Our group in their earlier work reported the detailed Mössbauer spectroscopic studies of iron mineralogy of samples collected from various drilled wells, in three petroliferous basins of India viz. Jaisalmer basin, Cambay basin and Eastern Krishna Godavari basin (EKG). In these studies, distribution of iron bearing minerals as the function of well depth have been reported [1–5].

The well sediments, irrespective of their geographical location mainly show presence of pyrite, jarosite (sulfur), siderite, ankerite (carbonates), hematite (oxide) and Fe^{2+} or Fe^{3+} containing clay minerals. However, the relative distribution of iron minerals as a function of depth was different in samples collected from different wells. But the distribution follows some systematic trend for a basin. This distribution pattern show correlation with the prospecting of a basin. For example clay (iron in Fe^{3+} state) and carbonate minerals were dominating in Jaislmer basin (where no oil was discovered till date) [1–3] while sulphur containing minerals and clay (Fe^{2+} state) was dominating in other two basins, which are oil producing basins [4,5].

MØrup et al. [6] have also reported Mössbauer spectroscopic studies of samples collected from North Sea petroliferous basin which is a major oil producing basin. This study show in these samples iron is dominantly present in the form of pyrite and clay minerals. Further in clay minerals also iron was dominantly present in the form Fe^{2+} but oxide phases were meagerly present. Result obtained by us and by MØrup et al. was further strengthened by study recently reported in literature on Mud-Volcanic samples [7].

Recently, an extensive drilling has been undertaken by Oil India Limited (OIL) in Bikaner–Nagaur petroliferous basin. Their studies revealed that basin has potential for heavy viscous oil. Due to some technical difficulties economical exploration of oil is yet to be started in this basin.

In present investigation, we have further extended Mössbauer spectroscopic studies of deep subsurface sediments collected from two representative wells Lunkha-1 and Pinodha-1 wells of Bikaner–Nagaur basin. It is worth pointing out and to the best of our knowledge that this study is interesting from the fact that it is the first Mössbauer spectroscopic study of samples collected from Bikaner–Nagaur basin it is also the first Mössbauer Spectroscopic study of only basin containing heavy viscous oil. This basin is again a centre of attraction as thick sedimentary sequence of Palana lignite Formation is encountered here. Palana lignite is one of the major coal fields of our country.

The aim of present study is

(a) to get information about relative distribution of chemical state of iron as a function of depth in the samples collected from wells,
(b) to get information about geochemical environment in which various well sediments were deposited by studying their iron mineralogy,
(c) to compare distribution of iron minerals in Palana Formation which is deposited in pure terrestrial environment with Bilara and other Formation which were deposited in pure marine environment.

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Table 1
Stratigraphic details of well Lunkha-1 and Pinodah-1.

Formation	Depth interval (Lunkha-1) m	Depth interval (Pinodah-1) m	Age
Marh	289–500	–	–
Palana	500–675	–	Paleocene
Jaisalmer	–	364–796	Jurassic
Bhadura	675–932	796–952	Permo
Bap	932–1068	–	Carboniferous
Kherwa	–	952–982	–
Upper Carbonate	–	1068–1510	982–1347
Nagaur	1510–1846.5	1347–1460	Late Cambrian
HEG	1846.5–1914	1460–1558	Early Cambrian
Bilara	1914–1957.5	1558–1645	Earliest Cambrian to Late Protozoic
Jodhpur	1957.5–1978	–	Protozoic

This may provide information about relative distribution of iron in two different environments.

2. Brief description of basin and test wells Lunkha-1 and Pinodah-1

The discovery of non-biodegradable, heavy oil from wells of Bikaner–Nagaur basin opens a new exploration field in N–W India. Thermal maturation- dependent bio markers ratios indicate that the oil was generated from a source rock within the early window. Source dependent biomarkers in the oil indicate that it originated from a marine carbonate rich source that contains oil and bacterial organic matter with no higher plant input and was deposited under anoxic conditions. Age diagnostic biomarkers in the oil indicate that the source rocks of Bikaner–Nagaur basin are deposited in Late Cambrian, Early Cambrian, Earliest Cambrian and Late Protozoic sedimentary sequence. Source rock studies indicate that oil present in these wells originated from marginally mature, organic rich rock in which phytoplankton are laminated with dolomites of the Precambrian Bilara Formation. More importantly, significant amounts of petroleum could have been generated from the equivalents of the proposed Bilara source rock, which are buried more deeply to the west of Bikaner–Nagaur basin in Pakistan and migrated in this basin [8–10].

Lunkha-1 is located at latitude-28°39′14″ and longitude-72°53′44″ This well penetrates various Formations, recent, Marh, Palana, Bhadaura, Bap, Upper Carbonate, Nagaur, HEG, Bilara and Jodhpur. Below Jodhpur Formation basement was encountered. Stratigraphic details are provided in Table 1.

Pinodah-1 is located at latitude 27°24′59″ and longitude 71°09′56″ This well penetrates various Formations viz recent, Jaisalmer Bhadura & Bap, Kherwa, Upper-Carbonate, Nagaur, HEG, Bilara and Jodhpur. Below Jodhpur Formation basement was encountered. Stratigraphic and geographical data were provided by Oil India Limited, Jodhpur.

Table 2
Mössbauer parameters obtained for various samples for well Lunkha-1.

Depth (m)	Doublet	IS (mm s^{-1})	QS (mm s^{-1})	LW (mm s^{-1})	Relative area (A) (%)	HMF (k Oe)
Jaisalmer						
540	BB′	1.13	2.499	0.518	56.7	–
	CC′	0.27	0.71	0.765	43.3	–
570	DD′	1.16	2.19	0.86	78	–
	CC′	0.13	0.75	0.566	22	–
595	DD′	1.11	2.45	0.555	62.1	–
	CC′	0.23	0.68	0.737	37.9	–
620	BB′	1.2	1.75	0.425	92.72	–
	CC′	0.13	0.48	0.411	7.28	–
Bhadura + Bap						
695	CC′	0.21	0.52	0.578	30.38	–
	NN′	0.07	0.34	0.381	100	–
Nagaur						
1740	Sextet	0.38	−0.07	1.559	78.46	496.34
	CC′	0.11	0.55	0.631	21.54	–
HEG						
1910	CC′	0.21	0.67	0.745	62.5	–
	DD′	1.13	2.39	0.416	0.416	–

Table 3
Mössbauer parameters obtained for various samples for well Pinodah-1.

Depth (m)	Doublet	IS (mm s^{-1})	QS (mm s^{-1})	LW (mm s^{-1})	Relative area (A) (%)	HMF (k Oe)
Palana						
520	DD′	1.24	1.85	0.249	46.16	–
	CC′	0.37	0.51	0.421	31.6	–
	DD′	0.99	2.12	0.449	22.24	–
570	BB′	1.25	1.58	0.214	17.9	–
	CC′	0.35	0.52	0.638	47.02	–
	DD′	1.24	2.45	0.582	35.08	–
585	BB′	1.15	1.61	0.52	72.94	–
	CC′	0.28	0.89	0.521	27.06	–
618	BB′	1.24	1.78	0.391	51.08	–
	CC′	0.30	0.63	0.344	48.92	–
678	BB′	1.24	1.84	0.315	63.58	–
	CC′	0.30	0.60	0.577	36.42	–
738	BB′	1.24	1.75	0.404	87.68	–
	CC′	0.28	0.54	0.338	12.32	–
783	BB’	1.18	1.82	0.346	55.78	–
	CC′	0.24	0.65	0.333	44.22	–
Bhadura + Bap						
858	BB′	1.24	1.87	0.316	55.38	–
		0.30	0.67	0.39	44.62	–
903	C_1C_1'	0.18	0.27	0.252	62.12	–
	C_1C_2'	0.19	0.84	0.316	37.88	–
Upper Carbonate						
1002	BB′	1.25	1.59	0.23	28.34	–
	CC′	0.29	0.47	0.537	71.66	–
1090	NN′	0.78	1.51	0.241	16.80	–
	CC	0.21	0.42	0.415	83.20	–
1160	CC′	0.22	0.45	0.46	52.10	–
	NN′	0.21	1.68	0.486	47.90	–
1210	CC′	0.25	0.61	0.384	57.56	–
	BB′	1.21	1.71	0.4930	42.44	–
1244	CC′	0.26	0.71	0.516	16.93	–
	DD′	1.27	2.17	0.761	83.07	–
1260	NN′	0.27	0.25	0.754	100	–
Nagaur						
1364	CC′	0.20	0.43	0.337	38.40	–
	DD′	0.85	2.19	0.364	37.86	–
	NN′	1.53	1.87	0.417	23.74	–
1404	Sextet	0.39	−0.20	0.919	62.20	508.75
	CC′	0.27	0.45	0.516	18.22	–
	DD′	1.19	2.71	0.497	19.58	–
1446	Sextet	0.19	−0.1	0.885	55.26	508.46
	CC′	0.15	0.67	0.657	14.04	–
	DD′	1.17	2.54	0.541	30.70	–
1460	CC′	0.24	0.495	0.453	34.62	–
	DD′	1.04	2.31	1.445	65.38	–
HEG						
1492	Sextet	0.43	−0.17	1.065	58.78	509.79
	CC′	0.24	0.73	0.731	22.46	–
	DD′	1.20	2.53	0.479	18.76	–
1526	Sextet		Fe_2O_3			–
1554	BB′	1.20	1.79	0.271	33.58	–
	CC′	1.32	2.22	0.379	17.72	–
		0.19	0.77	1.03	48.68	–
Bilara + Jodhpur						
1582	DD′CC′	0.98	2.14	0.238	16.24	–
		0.22	0.57	0.352	83.76	–