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Sedimentology of Chitarwata Formation, Rakhi Nala, Sulaiman Range, Pakistan

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ABSTRACT

The Oligocene-Miocene molasse have been developed throughout Potwar, Sulaiman and Kirthar provinces due to uplifting caused by Himalayan Orogeny. In Sulaiman region the molasse is stratigraphically designated as Chitarwata Formation. The formation is exposed as north-south trending strip in the eastern margin of Sulaiman Range. Thirteen samples of the formation were collected from Rakhi Nala and analyzed sedimentologically. Chitarwata Formation (Oligocene-Miocene) is grayish-white, medium to fine grained, mesokurtic, fine skewed quartz arenite. Grains are subrounded to subangular. It consists of mainly quartz bonded by calcareous and ferruginous cement. The data plotted on Visher graph, show that Chitarwata Formation was deposited in fluvio-deltaic to near shore environment. Similar observation was also made on the basis of grain size pattern and plots of median diameter versus skewness and phi deviation. High Fe and low Mg further confirmed freshwater to near shore deposition. The plots of SiO_2 versus log (K_2O/ Na_2O) suggest that Chitarwata Formation have tectonic affiliation with passive continental margin. These sediments have been deposited by recycling of older rocks due to Himalayan orogeny, also revealed from quartz-feldspar-lithic fragments triangular variation diagram.

Key words: Sedimentology, chitarwata formation, sandstone, rakhi nala, sulaiman range

INTRODUCTION

Sulaiman Range is one of the largest ranges of Pakistan (Fig.1) and occupies major part of Middle Indus Basin. The range is an established gas prone area with many discoveries such as Sui, Uch, Zin, Pirkoh, Loti, Jandran, Qadir Pur and Savi Ragha. The range consists of exposed rocks from Jurassic to Recent (Table 1). However older, formations are encountered in many drilled wells. Radioactive mineralization is also common in the Siwalik (Middle Miocene to Pliocene) molasse deposits.

The Chitarwata Formation of Oligocene-Miocene age is widely exposed as a north-south trending strip in the eastern margin of Sulaiman Range (Fig. 2). It shows decrease in thickness from north (Domanda, 380 m) to south (Rakhi Nala, 45 m). It is deposited in a fluvio-deltaic to near-shore environment. In the Rakhi Nala Section, it is grayish white, medium grained, poor to medium sorted, sub-rounded to sub-angular, porous, permeable and friable sandstone (Shah, 2002). These characters may designate the Chitarwata Formation as a good reservoir. Hemphill and Kidwai (1973) presented a good document on Chitarwata Formation. Since than, little attention has been paid to evaluate important characteristics of Chitarwata Formation. Present study deals with sedimentological characteristics through grain-size and thin section analyses. It also assisted to asses the mechanism of transportation and deposition of the formation. Major element geochemistry of cementing materials is also presented, which will facilitate not only the reservoir characteristics for hydrocarbons but also insight the possibilities of sandstone-hosted mineral deposits such as iron, copper and uranium.

General geology and stratigraphy

The Sulaiman Range is part of the fold-and-thrust system along the northwestern margin of the Indo-Pakistan Plate. The 250 km broad Sulaiman fold belt is bounded to the West by the left lateral strike slip Chaman fault zone. The foredeep basin to the East and South of the active Sulaiman lobe is formed mainly as a result of tectonic compression between the Indian Plate and Afghan Block. Sulaiman lobe is developed by transpression as a result of left lateral strike slip motion along the Chaman fault and Southward thrusting along the Western terminus of the India sub-continent (Lawrence *et al.*, 1981; Farah *et al.*, 1984 and Quittmeyer *et al.*, 1979).

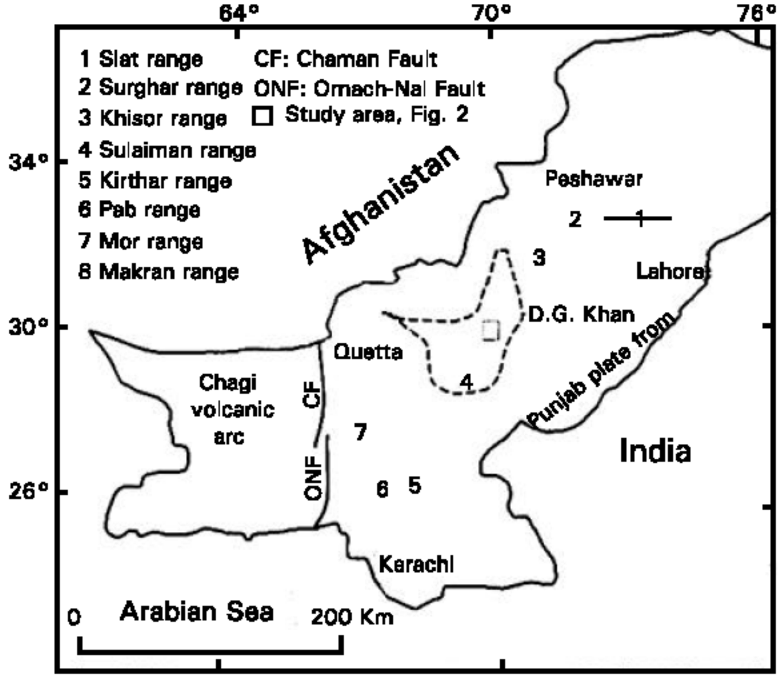

Fig. 1: Map showing Sulaiman and other ranges of Pakistan study area

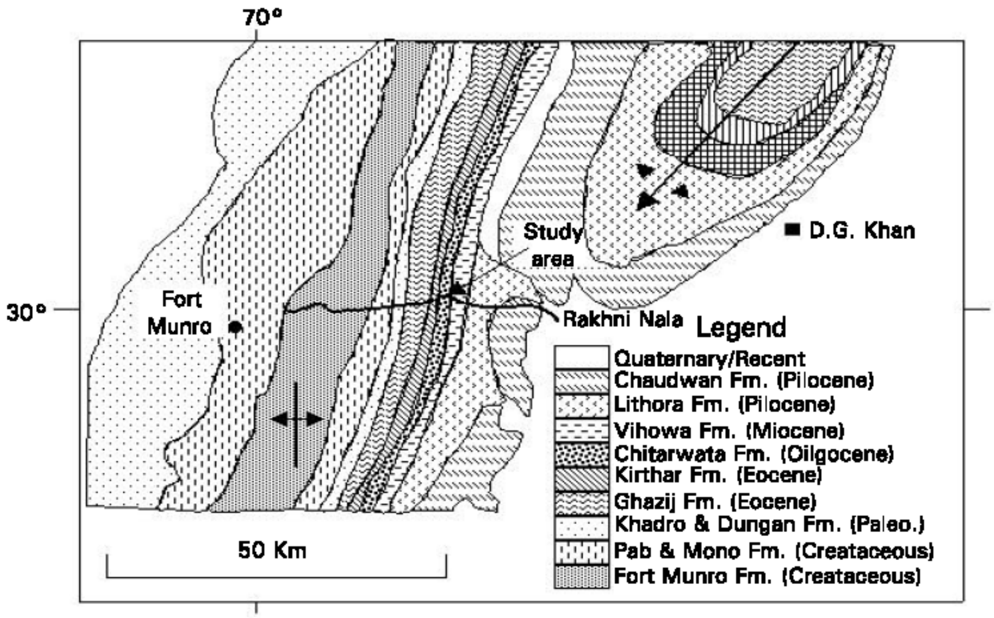

Fig. 2: Geological Map of study area (After Akhter and Masood, 1991)

The main structural elements in the Sulaiman fold belt are east-west trending arcuate folds and faults (Fig. 2), which rotate rapidly to a north-south direction along the margin of the active fold belt. Imbricate faults are visible at the surface only in the North (HSC, 1960; Kazmi and Rana, 1982).

The most important lithostratigraphic variations observed in Sulaiman Depression and the Fold Belt is in Paleocene/Eocene. This period marked the facies changes from north to south and east to west. The reason for this variation is believed to be the presence of a number of new basins at that time, created due to collision of plates and their irregular and non-uniform coalescence (Kadri, 1995). In late Eocene, collision and rotation between Eurasian and Indian plates intensified and major transform faults, namely Chaman and Ornach-Nal faults began to develop and Neo-Tethys was virtually consumed leaving behind small sub-deltaic ponds separated by local intra-plate uplifts.

Table 1: Stratigraphy of Sulaiman Range (After Akhter and Masood, 1991)

Age	Formation	Lithology	Thickness(meters)
RECENT	ALLUVIUM		6-7
	.........*UNCONFORMITY*.......		
PLEISTOCENE	CHAUDHWAN FORMATION	Conglomerate with claystone and sandstone	650-2200
PLIOCENE	LITRA FORMATION	Sandstone with Claystone and Conglomerate	750-2000
MIOCENE	VIHOWA FORMATION		
	.........*UNCONFORMITY*.......	Claystone with Sandstone	300-1000
OLIGOCENE-MIOCENE	CHITARWATA FORMATION		
	.........*UNCONFORMITY*....	Sandstone with Siltstone and Claystone	130-300
E.EOCENE-MIDDLE EOCENE	KIRTHAR FORMATION	Limestone, Marl, Shale and Claystone	300-950
E.EOCENE	GHAZIJ FORMATION	Shale. Limestone and Gypsum	140-600
PALEOCENE-E.EOCENE	DUNGHAN FORMATION	Limestone with Shale, Marl and Conglomerate	125-350
M.PALEOCENE	BARA FORMATION	Sandstone, Shale and minor Volcanic debris	60-140
PALEOCENE	KHADRO FORMATION	Sandstone with Shale, Siltstone and Limestone	160-360
L. CRETACEOUS	MORO FORMATION		
	PAB SANDSTONE		
	FORT MUNRO FORMATION		
	MUGHAL KOT FORMATION		
	PARH LIMESTONE		
U.JURASSIC-E.CRETACEOUS	SEMBAR FORMATION	Sandstone with Limestone and Shale.	54-160
		Quartzose sandstone with Shale.	390-420
		Limestone with Marl and Shale.	100-300
		Sandstone, Claystone and Limestone.	160-1170
		Limestone.	268-600
		Clayston with Limestone and Sandstone	133-262

Tectonic activity related to the Himalayan Orogeny commenced during the late Eocene and continued through the Oligocene, Miocene, Pliocene and Quaternary. Oligocene is marked by the most dramatic changes in the climate due to Himalayan Orogeny, which caused marine regression from north to south. During this period shallow water clastic sediments were deposited in this part of Indus Basin. In the Potwar region, Muree Formation is fluvial in nature, whereas Nari Formation is mainly marine and developed in the Lower Indus Basin. Chitarwata Formation is transitional between them.

Exposed rocks in the Sulaiman area can be divided into three main groups to emphasize their tectonic significance (Raza *et al.*, 1989). 1. Permian to Eocene shallow marine shelf to deep marine rocks exposed in the fold belt area (Kazmi and Rana, 1982); 2. Late Eocene to early Oligocene Khojak Flysch deposited between the Chaman fault to the West and Muslimbagh Ophiolite in the East and 3. Late Oligocene to Recent molasse deposited at the deformation front. (Lawrence and Khan, 1991).

Chitarwata formation

Chitarwata Formation is present throughout in the foothills of the Sulaiman Range (Fig. 2) and southern part of the Bugti Hills. The formation appears thin in the northern most parts and may wedge out along the western flank of Sorai Ghar in Waziristan, while it is 400 m thick southwest of Domanda and 500 m in Chitarwata and Kanra Nalas. It is almost uniform in thickness throughout the Dera Ghazi Khan area. Its thickness at Baghobandki is 250 m. It is 370 m in Khalgin Nala in Bugti area (Shah, 2002). In Dera Ghazi Khan and adjoining areas, Chitarwata Formation consists of variegated sandstone, siltstone and clay stone. The sandstone is reddish brown and grayish white coloured; medium to fine grained, grains are sub-rounded to sub-angular, thin to thick bedded friable and calcareous in places. The siltstone is reddish brown, friable, calcareous and ferruginous. The claystone is reddish brown and ferruginous (Akhter and Masood, 1991). The upper and lower contacts of Chitarwata Formation are unconformable. The lower contact with the Kirthar Formation is disconformable with ferruginous beds marking the contact. The upper contact with the "Siwalik Group" is also disconformable and is distinguished by a conglomeratic unit containing rust coated sandstone and limestone pebbles (Shah, 2002).

On the basis of these properties Chitarwata Formation can serve as a good reservoir in the middle and northern part of Sulaiman Range. Eni-LASMO Oil Pakistan has drilled a dry well (Ramak 1) southwest of Dera Ismail Khan, considering Chitarwata Formation as probable reservoir. Reservoir quality was proved to be good in outcrop and fair in the subsurface with average porosities of 16% and 9% respectively (Watts and Ali, 1994).

MATERIALS AND METHODS

Samples of Chitarwata Formation were collected from section close to Rakhi Nala in Sulaiman Range. Friable samples were used for direct grain size analysis. Grain size analysis of indurated sandstone was conducted by disintegration of original rock samples into their component particles. Through chemical treatments, all collected samples were prepared for grain size analysis using standard sieving and sedimentation techniques of Griffith (1967) and Tucker (1988). Thin sections of relatively harder samples were prepared in the laboratory of Geological Survey Pakistan (GSP), Karachi. Thin sections of sandstone were prepared and studied with the help of Polarizing microscope (Laborlux Pols). Photomicrography of selected samples was done with the help of Photoautomat Wild Leitz (MPS 46). For chemical analysis, samples were digested in Aqua Regia. Sodium and K were estimated using Gallenkamp FGA 350L flame-photometer. Silica (SiO_2) was determined gravimetrically, Ca and Mg were measured by EDTA titration.

RESULTS AND DISCUSSION

Grain size analysis

Particle size distribution is one of the basic descriptive characters of clastic sediments, which is important in understanding the mechanism operative during transportation and deposition, as well as the distance of sediment transport. Particle size also determines properties such as porosity and permeability. Particle size distribution analysis through sieving is presented here (Fig. 3). The data was analyzed through statistical means.

Samples of Chitarwata Formation are composed of medium to fine-grained sand with moderate sorting. The Sandstone is generally friable and loosely cemented, grains are subangular to subrounded, due to loose packing permeability is high. Also relatively lesser amounts of silty and clayey material in Chitarwata sandstone cause the high permeability.

The values of kurtosis for Chitarwata sandstone show the Mesokurtic or moderately sorted sands (Table 2). It has medium porosity and high permeability. The roundness of grains indicates notable amount of transportation of material from source to basin of deposition. According to Visher (1969) the data, plotted on probability scale, show that Chitarwata sandstone was deposited in fluvio-deltaic to near-shore environment (Table 3).

Thin section study

The samples of Chitarwata Formation in thin section shows quartz as main constituent (Fig. 4); lesser amounts of silt and clay matrix are also present. Quartz grains are highly fractured that show the tectonic pressure (Fig. 4A). Occurrence of microfractures within the detrital quartz grain is the evidence of burial diagenesis due to compaction (Mujtaba and Memon, 1990). These microfractures have been filled by authigenic quartz or $CaCO_3$ cement, indicating that cementation took place after compaction. Overgrowth of quartz can be produced quite adequately by the pressure solution of the original clastic quartz. The quartz dissolved at their points of contact and silica in solution is immediately precipitated as secondary quartz around the grains in position of low pressure. This is mineralogically mature sandstone in which quartz is the dominant constituent with minor feldspar, lithic fragments crert, biotite and muscovite (Fig. 4B and C). Heavy minerals are also present in which magnetite, garnet and tourmaline are common. It is loosely cemented sandstone. Siliceous, ferruginous and calcareous type of cement is common. Reddish- brown patches indicate ferruginous cement. Stylolytic boundaries show that dissolution was caused by the interaction between overburden stress and pore water. The samples have fairly high porosity, which is mostly intergranular and it is reduced due to diagenetic changes like compaction, overgrowth of quartz, calcitic cementation and pore pressure solution effect.

Microscopic and chemical studies of Chitarwata sandstone show the varieties of cement in which siliceous, calcareous and ferruginous cements are included (Table 4). These cements are results of deep burial, pressure solution, chemical dissolution and precipitation from saturated solutions. Siliceous cement was deposited in the form of overgrowth of silica on the detrital quartz grains (Fig. 4A) Sutured contacts among grains show the pressure solution effect. Sippel (1968) has suggested that many sutured grain contacts also arise from the growth interference of secondary growth on detrital grains. For cementation a specific environment for precipitation must be necessary so that for siliceous cement there would be acidic and low pH environment.

Besides siliceous, calcareous cement is also present in Chitarwata sandstone but all cements were not deposited at the same time instead they were deposited in response to the environments and saturation of particular component in the pore fluids. Both calcite and quartz occur as cement in sandstone, the calcite usually postdates the quartz. Boundaries between quartz cement, which occurs as overgrowths on quartz particles and calcite cement indicate that

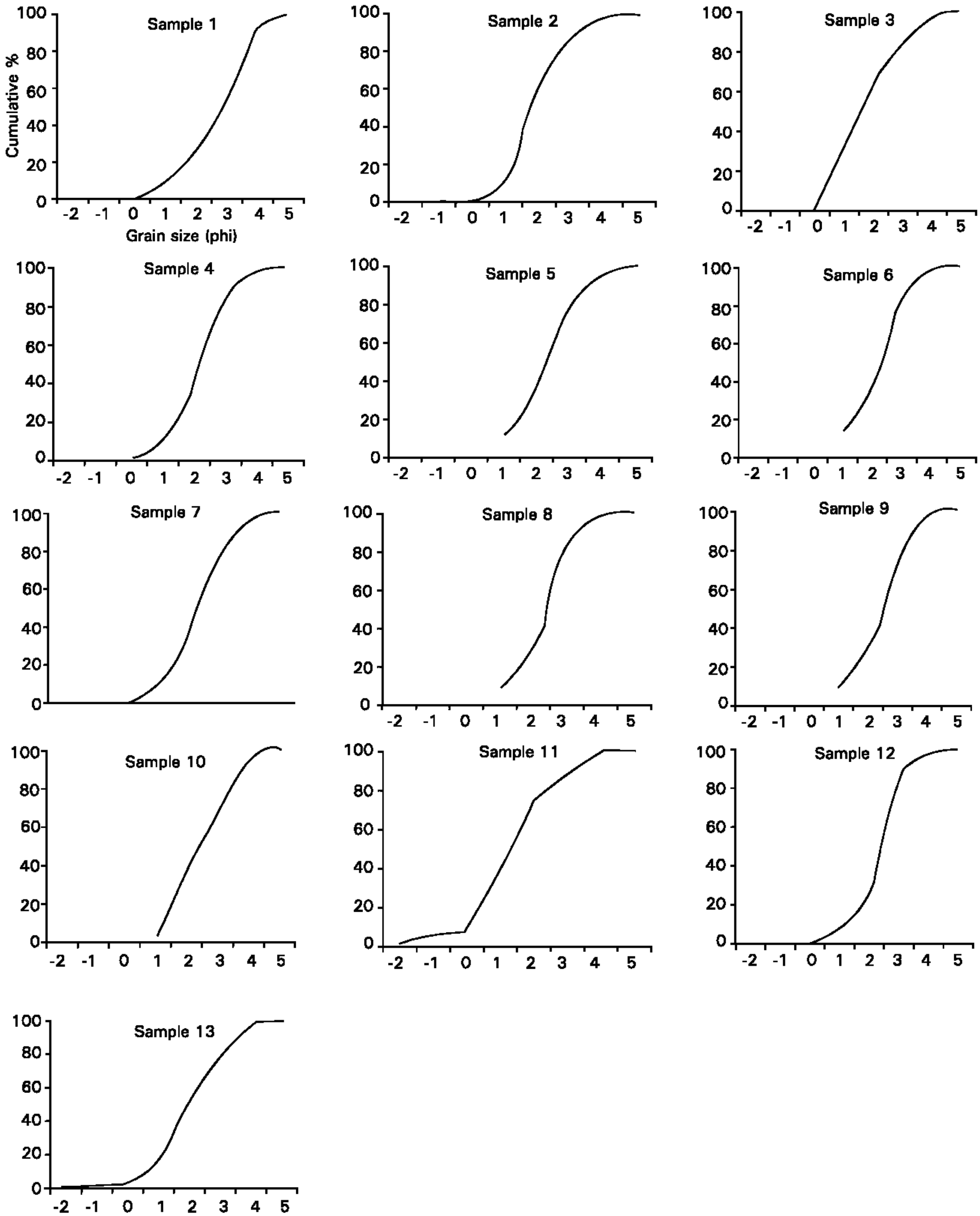

Fig. 3: Grain size analysis of Chitarwata Sandstone

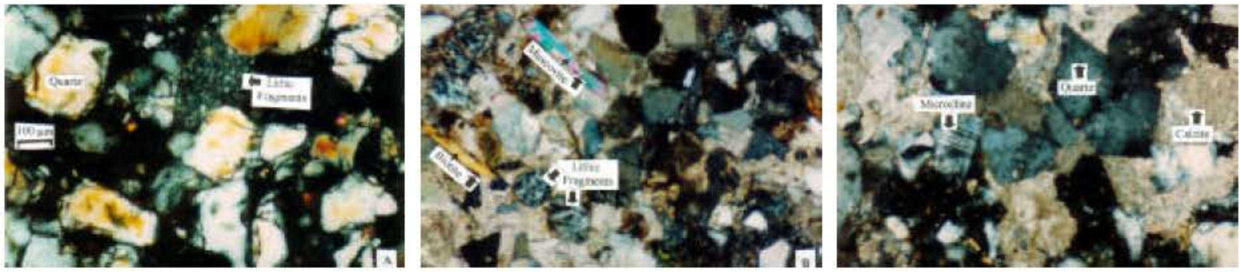

Fig. 4: Photomicrographs of Chitarwata Formation showing mineralogy, texture and digenetic attitudes A) Sample No. 1, B) Sample No. 5 and C) Sample No. 12. Cross Nicols

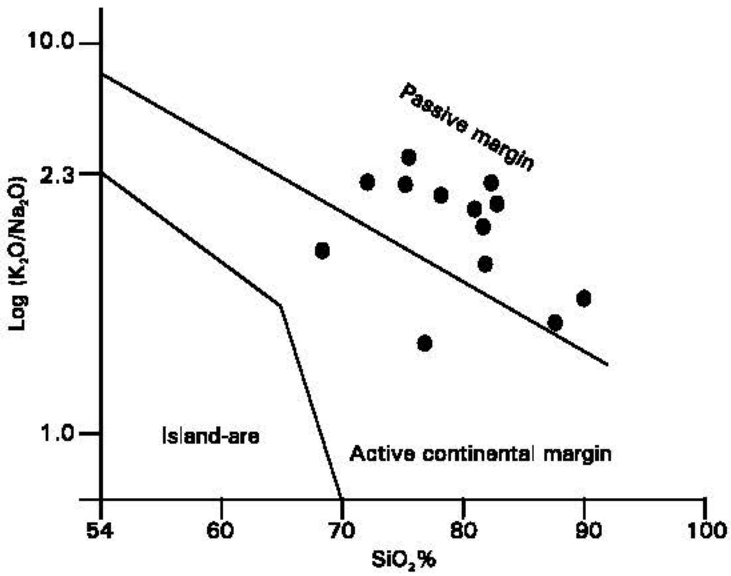

Fig. 5: The plots of log K_2O/Na_2O vs. SiO_2 showing dominance of passive continental margin as environment of cementation (After Rosser and Korsch, 1986)

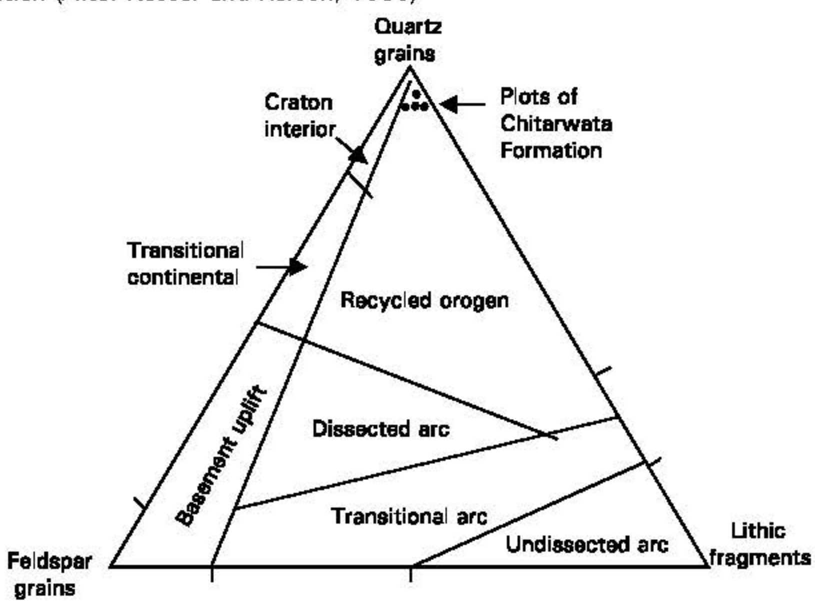

Fig. 6: Discrimination diagram showing Recycled orogen as provenance of Chitarwata Sandstone (After Dickinson, 1985)

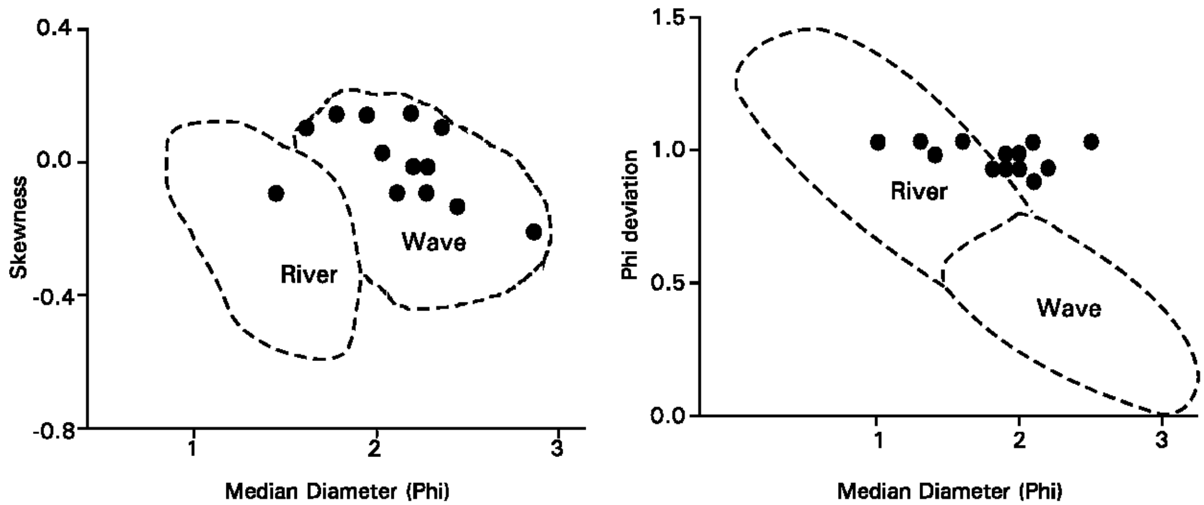

Fig. 7: Depositional environment of Chitarwata Sandstone based on statical parameters

the calcite was deposited later than the overgrowth. Where deposition of overgrowth occur later than the interpenetration of adjacent particles, the sequence commonly is (1) initial particle interpenetration (2) deposition of quartz cement (3) crystallization of calcite in remaining void spaces and as replacement of quartz. The $CaCO_3$ might be locally derived as a result of the dissolution of limestone bedrocks and precipitated from $CaCO_3$ saturated pore waters in high pH and basic environment. Ferruginous cement in Chitarwata sandstone shows the oxidizing environment of deposition, probably Fe was derived from the dissolution of iron bearing rocks.

Geochemistry

Normative mineralogical analysis of Chitarwata sandstone is presented here (Table 4), is based on chemical analysis. Mineralogy of rock provides information about depositional environment, energy conditions, salinity, tectonics, depth, oxidation/ reduction, acidity and alkalinity of the basin. Average abundance of quartz (SiO_2) is about 79.72%, which indicates the tectonic instability of depositional basin due to rapid subsidence of basin. High percentage of quartz also point to the rapid sedimentation.

Average concentration of total iron (Fe_2O_3) is about 2.75% (Table 4) by weight. Iron is mainly present as cementing material and its high concentration reflects the shallow water alkaline environment of deposition because iron precipitates in basic environment in the form of oxides (Hematite and limonite) and become mobile in acidic environment. It also shows the positive redox potential that indicates oxidizing environment of deposition (Brownlow, 1996).

Average amount of calcite and dolomite in the samples of sandstone are 15.60 and 1.89% respectively. They mainly occur as cementing material and probably came through dissolution from limestones and squashing of shales of older formations and precipitate in slightly alkaline environment. In contrast to calcite, dolomite is very low, which is probably the reflection of low salinity of the diagenetic water (Tucker, 1990). Mean Mg/Ca ratio is about 0.038 that indicates river water deposition at approximately 350 mg/l TDS. However sample 5 has relatively high Mg/Ca ratio (0.28).

Average quantity of Na_2O and K_2O is 0.44 and 0.17 respectively. Very low concentrations of alkalis in the samples of Chitarwata Formation indicate lesser effect of chemical weathering and low concentration of feldspar in sediments. Low concentration of both these elements also indicates fresh water environment of deposition because total dissolved salts is directly proportional to concentration of Na_2O and K_2O.

Composition, provenance and tectonics: The Chitarwata Formation is composed of terrigenous sands that are produced by weathering and breakdown of preexisting sedimentary rocks. The sands were transported, sorted and modified by moving fluids. From these study it reveals as Quartz Arenite (Dott,1964) or Orthoquartzite (Folk,1968).

Composition of detrital sandstone can easily reflect the tectonic setting of its provenance region (Tucker, 2001 and Rollinson, 1993). The tectonic environment of deposition can also be determined by plotting log K_2O/Na_2O vs. SiO_2 (Roser and Korsch, 1986). The plots of log K_2O/Na_2O vs. SiO_2 (Fig. 5) show dominance of passive continental margin as environment of cementation. It shows good agreement for sedimentation on the trailing edge thick continental crust (Indian Plate) at passive continental margin.

Table 2: Statistical parameters of Chitarwata Sandstone

Sample #	Skewness	Remarks	Kurtosis	Remarks
1	-0.265	Coarse Skewed	1.138	Leptokurtic
2	0.250	Fine Skewed	1.042	Mesokurtic
3	0.218	Fine Skewed	0.868	Platykurtic
4	0.193	Fine Skewed	1.186	Leptokurtic
5	-0.094	Coarse Skewed	1.062	Mesokurtic
6	-0.039	Coarse Skewed	1.050	Mesokurtic
7	-0.018	Coarse Skewed	1.040	Mesokurtic
8	-0.002	Coarse Skewed	1.366	Leptokurtic
9	0.133	Fine Skewed	1.083	Mesokurtic
10	0.187	Fine Skewed	0.716	Platykurtic
11	0.122	Fine Skewed	1.008	Mesokurtic
12	-0.123	Coarse Skewed	1.655	VeryLeptokurtic
13	0.127	Fine Skewed	0.925	Mesokurtic

Table 3: Environment of deposition of Chitarwata Sandstone (After Visher, 1969)

	Saltation		Suspension	Rolling	
Sample #	C.T Phi	F.T Phi	F.T Phi	C.T Phi	Environment
1	2.8	4.6	>4.5	No limit	Wave zone
2	3.0	4.5	>4.5	No limit	Wave zone
3	1.5	3.3	3.5-4.5	No limit	Plunge zone
4	2.7	3.8	3.8-5.0	No limit	Wave zone
5	0.7	4.5	>4.5	No limit	Beach zone
6	2.8	3.9	3.9-5.0	No limit	Wave zone
7	1.8	4.1	4.1-5.0	No limit	Plunge zone
8	1.0	3.9	3.9-5.0	1.0	Beach zone
9	2.0	3.6	3.6-5.0	No limit	Wave zone
10	2.0	3.6	3.6-5.0	No limit	Wave zone
11	-0.2	3.9	3.9-5.0	-0.1-0.2	Beach zone
12	0.7	4.5	>4.5	>0.7	Beach zone
13	1.0	3.5	3.5-5.0	1-2	Beach zone

Table 4: Normative chemical analysis of Chitarwata Sandstone

Sample #	SiO_2	$CaCO_3$	$CaMg(CO_3)_2$	Fe_2O_3	Total%	Log (K_2O/Na_2O)
1	77.52	16.94	3.31	2.22	99.99	1.36
2	81.64	12.52	3.31	2.47	99.99	2.37
3	75.09	20.66	2.21	2.02	99.98	2.92
4	82.98	13.77	1.10	2.15	100.00	2.48
5	87.09	4.41	6.82	1.67	99.99	1.79
6	86.70	9.94	1.10	2.25	99.99	1.47
7	73.01	23.13	1.10	2.75	99.99	2.88
8	81.35	12.57	3.31	2.75	99.98	2.13
9	78.84	18.65	0.10	2.37	99.96	2.73
10	82.00	14.30	1.12	2.57	99.99	1.80
11	76.40	19.91	1.08	2.60	99.99	4.00
12	83.21	9.26	0.06	7.32	99.85	2.15
13	70.57	26.74	0.07	2.60	99.98	1.72

The modal analysis of quartz-feldspar-lithic grains in the form of triangular variation diagram (Dickinson, 1985) illustrates different provenances. The plots of Chitarwata Formation show tectonic relation with fold thrust belt (Himalayan) and recycled orogen as principal type of sedimentary provenance (Fig. 6). Grain size distribution and their statistical analysis (Median diameter, skewness and phi deviation) provides good reflection of environment of deposition (Fig. 7). Grain size distribution pattern (Fig. 3) designate dominance of fluvial to transitional environments. The plots of skewness and phi deviation vs. median diameter (Fig. 7) exhibit influence of near shore environment, which is characterized by both river and wave action.

Samples of Chitarwata Formation are composed of medium to fine-grained sand, which mainly consisting of quartz with feldspar, lithic fragments crert, biotite and muscovite and classified as quartz arenite. The Sandstone is friable and loosely cemented, the grains are subangular to subrounded.

The data plotted on Visher graph, show that Chitarwata sandstone was deposited in fluvio-deltaic to near shore environment. The roundness of grains shows the notable transportation of material from source to basin of deposition. The value of kurtosis for Chitarwata sandstone shows the Mesokurtic or moderately sorted sands. It has medium porosity and high permeability.

Microscopic and chemical studies of Chitarwata sandstone show the varieties of cement in which siliceous, calcareous and ferruginous cements are included. These cements are results of depth of burial, pressure solution, dissolution and precipitation of saturated solutions.

High concentration of Fe reflects the shallow marine oxidizing basic environment of deposition. Low Mg and Mg/Ca ratio indicates fresh to near shore water of deposition. Low alkalis (K and Na) also suggestive of deposition in low salinity water.

The plots of log K_2O/Na_2O vs. SiO_2 show dominance of passive continental margin as environment of cementation. It shows good agreement for sedimentation on the trailing edge thick continental crust (Indian Plate) at passive continental margin. The plots of Chitarwata Formation on quartz-feldspar-lithic grains variation diagram show tectonic relation with fold thrust belt (Himalayan) and recycled orogen as principal type of sedimentary provenance.

REFERENCES

Akhter, M. and T. Masood, 1991. A guidebook to Geology of Sulaiman Range: A publication of Geological Survey of Pakistan, pp: 24.

Brownlow, A.H., 1996. Geochemistry, Prentice Hall Inc. New Jersey, pp: 580.

Dickinson, W.R., 1985. Interpreting provenance relations from detrital modes of sandstones, In: Zuffa, G.G. (Ed.) Provenance of Arenites, Reidel, Dordrecht, pp: 333-361.

Dott, R.H., 1964. Wacke, greywacke and matrix-what approach to immature sandstone classification? Jour. Sed. Petrology, 34: 625-632.

Farah, A., R.D. Lawrence and K.A. Dejong, 1984. An overview of the tectonics of Pakistan, In: Haq, B.U. and Miuiman, J.D., (Eds.) Marine Geology and of Arabian Sea and Coastal Pakistan, Van Nostrand Reinhold Publisher, pp: 161-176.

Folk, R.L., 1968. Petrology of sedimentary rocks, The University of Texas, pp: 170.

Griffith, J.C., 1967. Scientific methods in analysis of sediments, McGraw Hill, USA, pp: 508.

Hemphill, W.R. and A.H. Kidwai, 1973. Stratigraphy of Bannu and Dera Ismail Khan areas Pakistan: GSP paper 716-B.

Hunting Survey Corporation, 1960. Reconnaissance geology of part of West Pakistan: A Colombo Plan Cooperative Project. Government of Canada, Geodynamic, Toronto, pp: 550.

Kadri, I.B., 1995. Petroleum Geology of Pakistan: Pakistan Petroleum Limited Publication, pp: 136-142.

Kazmi, A.H. and R.A. Rana, 1982. Tectonic map of Pakistan, Scale 1: 2,000,000: Geological Survey of Pakistan, Quetta.

Lawrence, R.D. and S.H. Khan, 1991. Structural reconnaissance of Khojak flysch, Pakistan and Afghanistan.

Lawrence, R.D., S.H. Khan, K.A. Dejong, A. Farah and R.S. Yeats, 1981. Thrust and Strike Slip fault interaction along the Chaman transform zone, Pakistan: Geol. Soc. London, Spec. pp: 336-370.

Mujtaba, M. and M.A. Memon, 1990. Diagenesis and pore space development of Datta Sandstones in Salt Range and Surgher Range, HDIP J., 2: 57-66.

Quittmeyer, R.C., A. Farah and K.H. Jacob, 1979. The seismicity of Pakistan and its relation to surface faults, In: A. Farah and Dejong, K.A. (Eds) Geodynamics of Pakistan: Geological Survey of Pakistan, Quetta, pp: 351-358.

Raza, H.A., R. Ahmed, S.M. Ali and J. Ahmed, 1989. Petroleum Prospects: Sulaiman Sub-Basin, Pakistan: Pakistan Journal of Hydrocarbon Research, pp: 1-20.

Rollinson, H.R., 1993. Using Geochemical Data, Longman Scientific and Technical, U.K., pp: 352.

Roser, B.P. and R.J. Korsch, 1986. Determination of tectonic setting of sandstone-mudstone suites using SiO_2 content and K_2O/Na_2O ratio, J. Geol., 94: 635-650.

Sippel, R.F., 1968. Sandstone petrology, evidence from luminescence petrography, Jour. Sed. Petrol., 38: 530-554.

Shah, S.M.I., 2002. Lithostratigraphic units of the Sulaiman and Kirthar Provinces, Lower Indus Basin, Pakistan, GSP Record 107, pp:62.

Tucker, M.E., 2001. Sedimentary Petrology, Blackwell Science, Oxford, pp: 262.

Tucker M.E., 1990. Dolomites and dolomitization models, In: Carbonate Sedimentology, eds. Tucker, M. E., Wright, V. P., Blackwell Sci. Pub. London, pp: 365-400.

Tucker, M.E., 1988. Techniques in Sedimentology, Blackwell Science, Oxford, pp: 394.

Visher, G.S., 1969. Grain size distribution and depositional process, Jour. Sed. Petrol., 39: 1077-1106.

Watts, K.J and M. Ali, 1994. The Petroleum Geology of the northern Sulaiman Foredeep, Pakistan, Petroleum Seminar, Jan. 23-24, 1994, Department of Geology, University of Karachi, (Abstract).