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# Geochemical Analysis of the Reservoir Rocks of Surma Basin, Bangladesh

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**Abstract** Geochemical analysis of three major gas fields (Kailastila (Well 2), Rashidpur (Well 4) and Fenchuganj (Well 2)) of the Surma Basin has been performed in this study to characterize source rocks and to understand the composition, rock types, and environment of accumulation of sediment of the basin. The XRF analytical result shows that the rock samples are comprised of moderate to high SiO2 contents (50–58%; on average 55%) with a significant amount of Al2O3 (~23%). The SiO2 content and the SiO2/Al2O3 ratio of the samples reflect the intermediate quartz richness. In trace element concentration, Arsenic (As) in the reservoir rocks is more than the permissible limit of WHO. Analyses using different discriminating diagrams show that the reservoir rocks of the Surma basin are mostly greywackey to litherenite. These rocks are deposited under active continental margin with quartzose provenance.

**Keywords** Geochemical analysis, Surma basin, Gas field, Reservoir rock, Active continental margin

## 1. Introduction

The geochemical analysis is the method through which scientists discover and unravel the chemical compounds that make up the earth, its atmosphere, and its seas. Geochemical analysis can predict where petroleum, metals, water, and commercially valuable minerals can be located. In recent years, petroleum geochemical analysis has been developed to characterize source rocks and to understand the origin, migration, and accumulation of petroleum. Geochemical and their solutions could yield tremendous competitive advantages in exploration and production. It is most powerful when used by other disciplines, such as seismic sequence stratigraphy and reservoir characterization.

The Surma Basin of Bangladesh (Figure 1) experienced a variety of sediment facies, indicating a range of depositional environments during the Neogene time [1]. Furthermore, during the Miocene time, the Sylhet Basin has a noticeable subsidence and marine transgression. The transgression of the Miocene certainly affected the coastline. It is believed that the Surma Basin has undergone two successive phases of evolution; the marine transgressive phase, followed by a regressive phase resulting in a series of continental fluvio-deltaic to marginal marine sedimentation during the Neogene. The Great Himalayan Orogeny and related tectonics subject the Surma Basin during the Miocene-Pliocene times. However, major changes in sea level for Neogene are transgressive-regressive phenomena suggested by [1]. Moreover, Bandy [2] pointed a marked rise in sea level would have caused a marine transgression.

An extensive geological and geophysical (mostly seismic) survey has been carried out in order to describe the stratigraphy, regional setting, structural evolution, condition of deposition of sediments and the paleogeography of the basin. Regardless of the study of the geology and petroleum prospects [3-6], comparatively few attempts [1, 7-10], have been made to study the geochemistry of the Surma Basin. However, the rock type of the reservoir with deposition tectonic setting still not clear for the Bengal basin. A range of sedimentary variation could be found due to sediment carried by different river systems in the Bengal basin. The sediment can also be deposited in the different tectonic setting. The proper geochemical analyses enable to address the raised questions. In this paper, we attempted to i) to determine the type of the rock sample, ii) to determine distinctive tectonic environments of the rock samples, and iii) to determine distinctive provenance characteristics of the samples.

## 2. Overview of the Study Area

Sylhet Trough (Surma Basin) (Fig. 1) Covers the northeastern part of the Bengal Basin, representing a promising petroleum bearing basin in the Southeast Asia. The basin is bounded on the north by the Shillong plateau, on the east and southeast by the Chittagong-Tripura fold belt of

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the Indo-Burman ranges and on the west by the Indian Shield platform, to the south and southwest it is open to the main part of the Bengal Basin. The thickness of the late Mesozoic and Cenozoic strata in the Surma Basin range is from about 13 to 17 km [11, 12], and much of this group is Neogene in age. Considerable interest has been focused over the past few decades concerning the geological investigation of the Surma Basin due to its petroleum prospective. There are several gas fields have been discovered within the basin.

Considerable contributions have been made by several investigators in relation to the regional geology, petroleum prospects, sedimentology and tectonic evolution of individual parts of the basin and adjoining areas (e.g. [1, 6, 12-19]. Surma Group (middle to late Miocene) consists of alternating sandstones, siltstones and mudstones and is lithologically divided into the mostly arenaceous Bhuban Formation and the dominantly argillaceous Bokabil Formation (Fig. 2). The Surma Group accumulated in interdeltaic to open marine depositional environments [20, 21].

## 3. Materials and Methods

Twelve (12) core sample has been collected from core storage at Chittagong of BAPEX (Bangladesh Petroleum Exploration & Production Company Limited) are given in the Table 1.

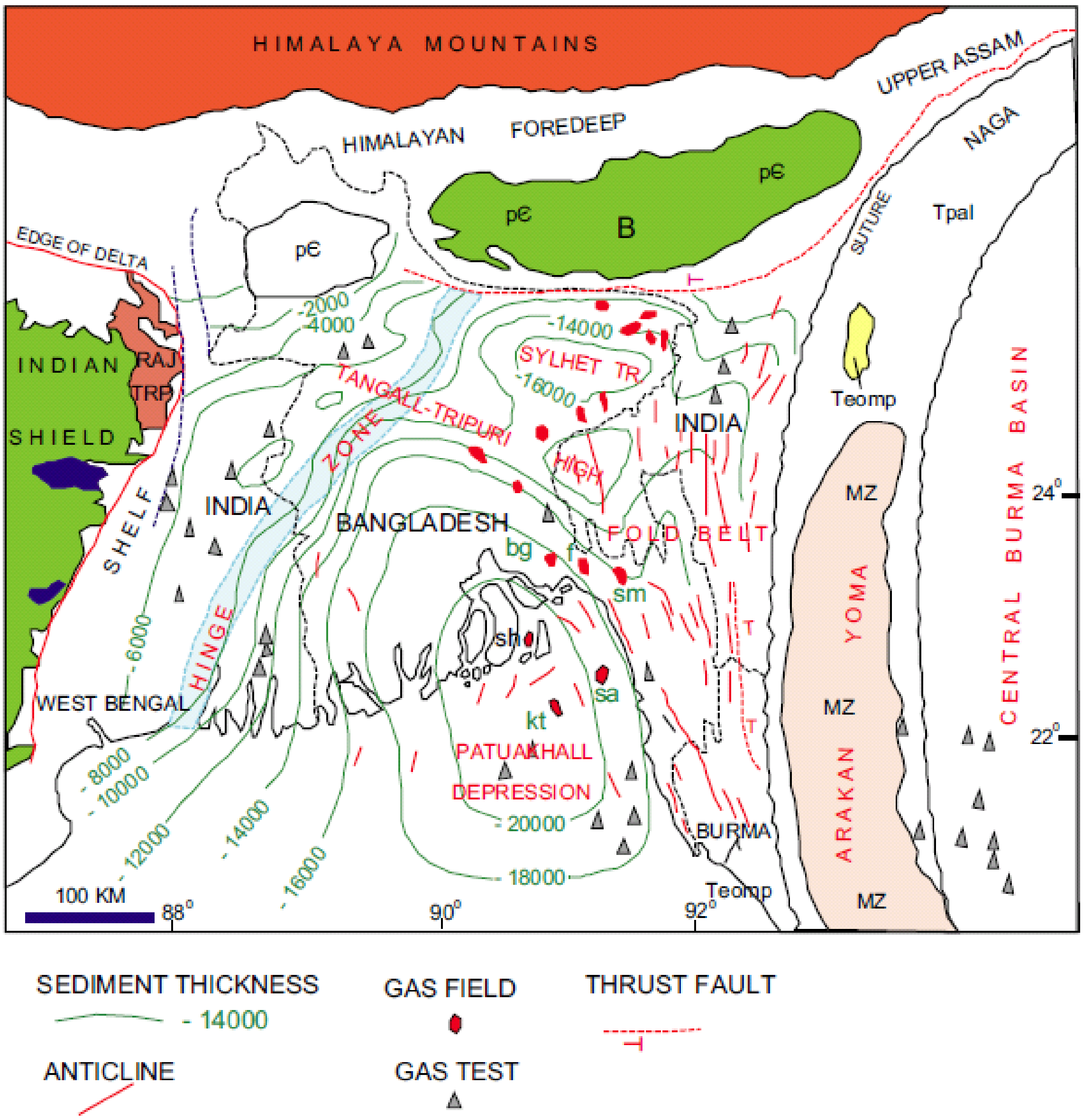


**Figure 1.** Generalized geological map of Bangladesh and adjoining area. Surma Basin is same as Sylhet Trough (after [13])

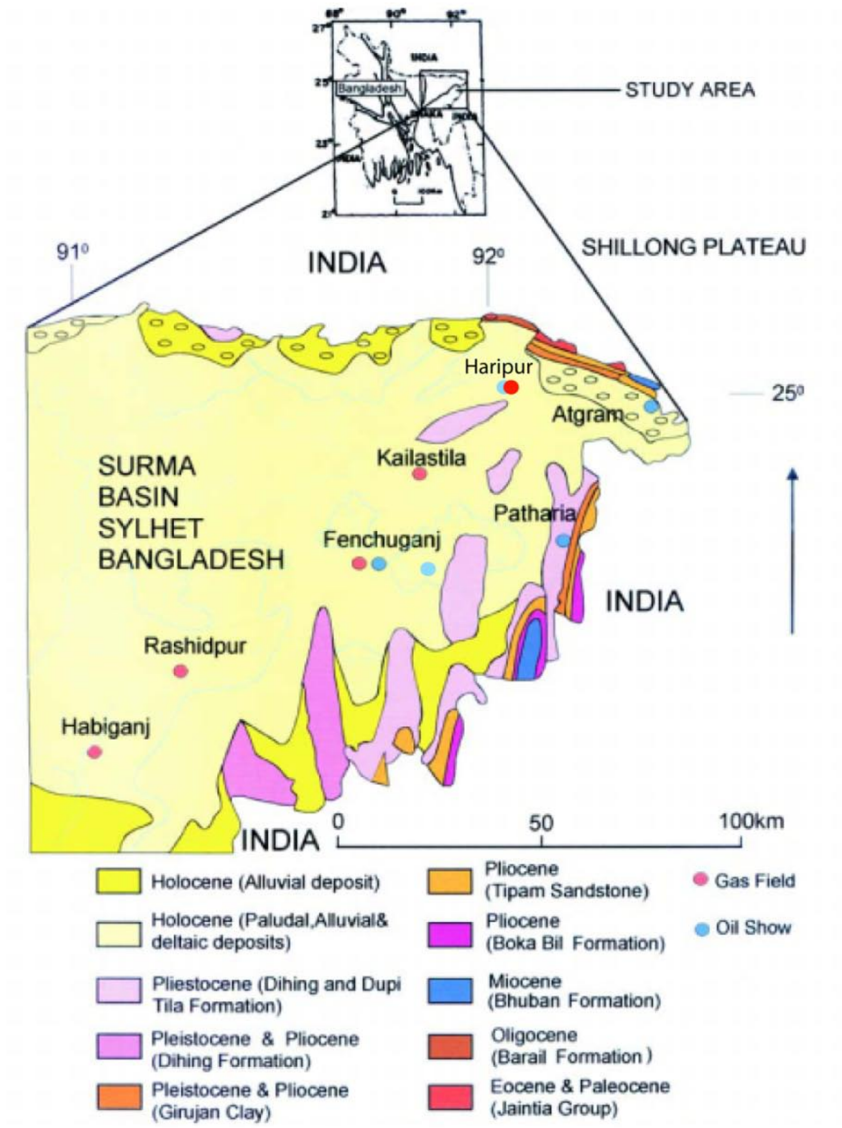


**Figure 2.** Map of the Surma Basin, Sylhet, Bangladesh with some prominent gas fields (after [1])

**Table 1.** Reservoir rock samples from the three gas field of different well at different depth

| Gas Field | sample No. | Name of the sample | Core No. | Box No | Depth of the sample |
|---|---|---|---|---|---|
| Kailastila (Well 2) | 01 | KTL#2 SL 1 | 11 | 13 | 9787'-9790' |
| | 02 | KTL#2 SL 2 | 13 | 19 | 9923'-9925' |
| | 03 | KTL#2 SL 3 | 8 | 6 | 9615'-9618' |
| | 04 | KTL#2 SL 4 | 12 | 11 | 9841'-9844' |
| Rashidpur (Well 4) | 05 | RP#4 SL 1 | 7 | Not Known | 8765'-8768' |
| | 06 | RP#4 SL 2 | 8 | Not Known | 8809'-8812' |
| | 07 | RP#4 SL 3 | 10 | Not Known | 8941'-8944' |
| | 08 | RP#4 SL 4 | 12 | Not Known | 9038'-9041' |
| Fenchuganj (Well 2) | 09 | FDP#2 SL 1 | 10 | 10 | 3624m-3625m |
| | 10 | FDP#2 SL 2 | 12 | 1 | 4086m-4087m |
| | 11 | FDP#2 SL3 | 11 | 8 | 3777m-3778m |
| | 12 | FDP#2 SL 4 | 4 | 2 | 3425m-3426m |

*X-ray Fluorescence Spectrometer study*

The selected samples were crushed for 20 minutes in a planetary ball mill (PM-200, Retsch, Germany) to make a powder form in well mixing conditions. The powder samples were then pulverized in a pulverize machine. The finely ground powder (<100 µm) was then put in a porcelain crucible and dried at 1000C in an oven overnight to remove moisture. The dried powder samples were mixed with a binder (citric acid: sample at a ratio of 1:10) and pulverized for two minutes. The resulting mixture was spooned into an aluminum cap (30mm). The cap was sandwiched between two tungsten carbide pellets using a manual hydraulic press with 10-15 tons/sq. in. for 2 minutes and finally pressure was released slowly. The pellet was then ready for x-ray analysis. The elements were determined by X-ray fluorescence (XRF) Spectrometer method at the Bangladesh Atomic Energy Commission, Dhaka following the procedures of [22, 23] using Rigaku ZSX Primus XRF machine equipped with an end widow 4 kW Rh-anode X-ray tube. The heavy and light elements were determined using 40kV voltage with 60mA current and 30kV and 100mA current respectively. The standards used in the analyses are the Geological Survey of Japan (GSJ) Stream Sediments (JSD 1, JSD 2 and JSD 3) and USGS Rock Standards (AVG 2, BCR 2, BHVO 2, BIR 1 and GSP 2). Analytical uncertainties for XRF major and minor elements are ~2% and trace elements are <10-15%.

Heavier elements were determined using crystal LiF1 at a 40kV voltage with 60mA current. The elements Ca and K were determined in 40kV and 60mA current with crystal LiF1, P was determined in 30kV and 100mA current with crystal GE, Si and Al were determined in 30kV and 100mA current with crystal PET, Mg and Na were determined in 30kV and 100mA current with crystal RX25.

# 4. Result and Discussion

*Rock type analysis*

Major element's data (Table 2) show that sandstones have moderate to high SiO2 contents (50–58%; on average 55%) with a significant amount of Al2O3 (~23%). However, the most commonly used geochemical criteria of sediment maturity are the SiO2 content and the SiO2/Al2O3 ratio [24], reflecting the intermediate quartz richness. However, the chemical maturity is the alkali content (Na20 + K2O), also a measure of the feldspar content. The chemical maturity can be measured using Na2O/K2O ratio. Pettijohn et al. [25] proposed a classification for terrigenous sands based upon a plot of log(Na2O/K2O) vs log(SiO2/Al2O3). This diagram is particularly shows the relationships between elemental composition, mineralogy and rock type, and is widely being used. Using the diagram, our analyzed samples are graywacke to litharenite sandstone (Fig. 3). However, the Na2O vs K2O discrimination diagram (after Crook, 1974 [26]) shows the intermediate richness of quartz (Fig. 4)

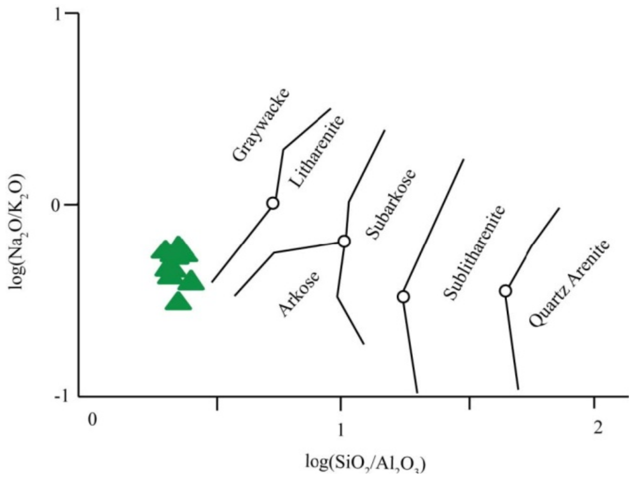


**Figure 3.** The classification of terrigeneous sandstones using log(Na2O/K2O) vs log(SiO2/A12O3) from [25], the boundaries drawn using [27]

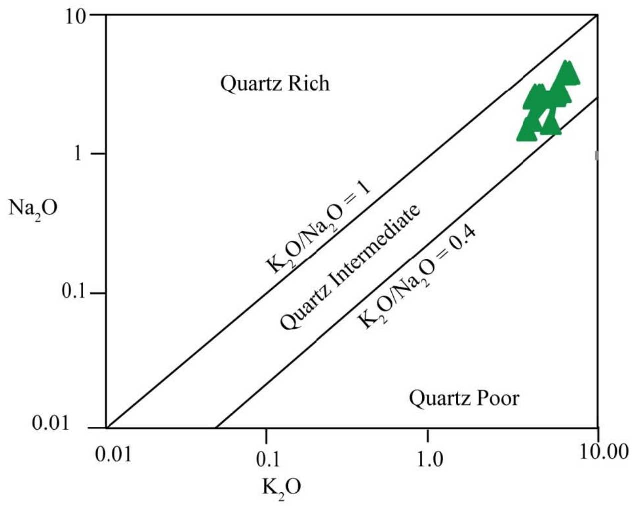


**Figure 4.** The K2O vs Na2O discrimination diagram after [28] for sandstone-mudstone suites and showing the fields for an abundance of quartz

*Tectonic environmental analysis*

Plate tectonic processes impart a distinctive geochemical signature to sediments in two separate ways. Firstly, different tectonic environments has distinctive provenance characteristics and, secondly, they are characterized by distinctive sedimentary processes. Sedimentary basins may be assigned to the following tectonic settings [28] for active continental margin, passive continental margin, oceanic island-arc, continental island-arc, and collisional setting.

The active continental margins are those that are tectonically active, and are marked by earthquakes, volcanoes, and mountain belts; whereas passive continental margins develop along coastlines that are not tectonically active. Fore-arc or back-arc basins, adjacent to a volcanic-arc developed on oceanic or thin continental crust. However, Bhatia [29] proposed a discrimination diagram based upon a bivariate plot of first and second discriminate functions of major element analyses (Fig.5). The discriminant functions were calculated as:

Discriminant function 1 = 0.0447SiO2 - 0.972TiO2 + 0.008Al2O3 - 0.267Fe2O3 + 0.208FeO- 3.082MnO + 0.140MgO + 0.195CaO + 0.719Na2O - 0.032K2O + 7.510P2O5 + 0.303

Discriminant function 2 = -0.421SiO2 + 1.988 TiO2 - 0.526Al2O3 – 0.551Fe2O3 – 1.610FeO + 2.720MnO + 0.881MgO – 0.907 CaO – 0.177Na2O – 1.840K2O +7.244P2O5 +43.57

The collected samples of this study fall in the active continental margins that are comparable with previous study [30], field in the discrimination diagram indicating depositional tectonic setting of the Surma Group sediments.

Moreover, the discrimination diagram of log (SiO2/Al2O3) vs (K2O/Na2O) (After [29]) for sandstone-mudstone suites (Fig. 6) also shows an active continental margin environment of sediment deposition, and are in good agreement with previous result [1, 30] and seismotectonic and tectonic reports of the region of other authors [31-36].

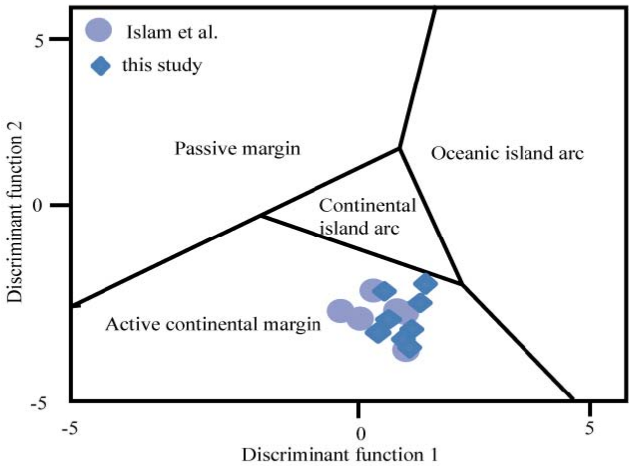


**Figure 5.** The discriminant function diagram for sandstones after [28], showing fields for sandstones from passive continental margins, oceanic island-arcs, continental island-arcs and active continental margins

**Table 2.** Major element analysis of reservoir rocks of the Surma Basin

| | Kailastila Gas Field | | | | Rashidpur Gas Field | | | | Rashidpur Gas Field | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Compound/ Elements | Sample 1 | Sample 2 | Sample 3 | Sample 4 | Sample 5 | Sample 6 | Sample 7 | Sample 8 | Sample 9 | Sample 10 | Sample 11 | Sample 12 |
| $SiO_2$ (%) | 50.232 | 56.871 | 52.615 | 54.754 | 56.037 | 54.475 | 52.101 | 55.678 | 54.176 | 55.919 | 58.283 | 54.678 |
| $Al_2O_3$ (%) | 22.184 | 24.423 | 24.184 | 22.252 | 23.918 | 22.637 | 23.449 | 23.157 | 23.640 | 22.259 | 22.294 | 22.479 |
| $Na_2O$ (%) | 1.750 | 3.850 | 3.820 | 2.560 | 2.821 | 2.550 | 2.630 | 1.650 | 2.712 | 1.488 | 2.558 | 2.500 |
| $K_2O$ (%) | 4.060 | 6.834 | 6.472 | 4.199 | 6.043 | 4.646 | 5.551 | 5.242 | 5.643 | 3.721 | 4.505 | 4.160 |
| CaO (%) | 2.764 | 1.564 | 0.573 | 1.617 | 1.574 | 1.522 | 3.555 | 3.777 | 2.026 | 1.568 | 0.743 | 0.735 |
| MgO (%) | 3.789 | 3.320 | 3.560 | 4.279 | 2.856 | 4.270 | 4.075 | 3.463 | 3.046 | 3.700 | 4.138 | 4.421 |
| $TiO_2$ (%) | 0.821 | 0.454 | 0.431 | 0.829 | 0.495 | 0.797 | 0.585 | 0.667 | 0.607 | 0.822 | 0.863 | 0.812 |
| $Fe_2O_3$ (total) (%) | 9.253 | 2.068 | 1.899 | 8.482 | 3.915 | 8.189 | 4.562 | 6.249 | 4.343 | 8.749 | 9.734 | 8.340 |
| $Fe_2O_3$(%) | 1.388 | 0.310 | 0.285 | 1.272 | 0.587 | 1.228 | 0.684 | 0.937 | 0.651 | 1.312 | 1.460 | 1.251 |
| FeO(%) | 7.865 | 1.758 | 1.615 | 7.210 | 3.327 | 6.961 | 3.878 | 5.312 | 3.691 | 7.436 | 8.274 | 7.089 |
| As (ppm) | 13.672 | 15.341 | 15.250 | 13.608 | 15.086 | 13.865 | 14.848 | 14.737 | 15.132 | 14.214 | 12.945 | 13.931 |
| Rb (ppm) | 74.270 | 67.256 | 68.065 | 73.982 | 69.025 | 73.158 | 69.798 | 71.542 | 69.849 | 75.593 | 73.258 | 74.198 |
| Sr (ppm) | 285.71 | 326.17 | 251.11 | 305.26 | 278.35 | 259.50 | 734.02 | 233.89 | 348.83 | 208.122 | 363.37 | 199.98 |
| Co (ppm) | 17.913 | 7.330 | 7.983 | 17.145 | 9.755 | 16.096 | 4.004 | 14.839 | 10.630 | 14.375 | 18.560 | 19.344 |
| Cr (ppm) | 68.873 | 84.132 | 70.453 | 68.165 | 80.814 | 78.936 | 65.912 | 70.181 | 64.165 | 76.242 | 69.527 | 76.933 |
| Cu (ppm) | 0.000 | 4.201 | 4.924 | 0.000 | 0.000 | 0.000 | 30.851 | 26.217 | 0.000 | 0.000 | 0.000 | 55.451 |
| Mn (ppm) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 579.30 | 0.000 |
| Ni (ppm) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| V (ppm) | 148.87 | 0.000 | 0.000 | 175.59 | 0.000 | 58.811 | 87.781 | 34.889 | 69.737 | 99.072 | 119.01 | 145.91 |
| Zn (ppm) | 103.73 | 58.524 | 46.453 | 105.60 | 64.098 | 93.875 | 134.08 | 87.475 | 75.246 | 91.076 | 92.025 | 104.65 |
| Se (ppm) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

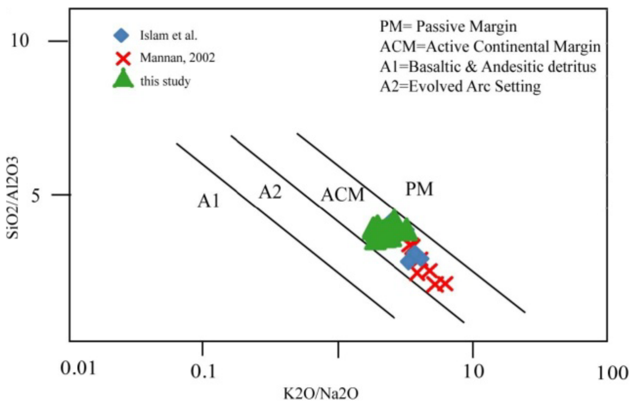


**Figure 6.** The log (SiO2/Al2O3) vs (K2O/Na2O) discrimination diagram after [29] for sandstone-mudstone suites

***Provenance Characteristics Analysis***

The provenance analysis includes all investigations that would help in reconstructing the lithospheric history of the Earth [37]. In sedimentary petrology, the term provenance has been used to encompass all factors related to the production of sediment, with specific reference to the composition of the parent rocks as well as the physiography and the climate of the source area from which sediment is derived. The goal of sedimentary provenance studies are to reconstruct and to interpret the history of sediment from the initial erosion of parent rocks to the final burial of their detritus.

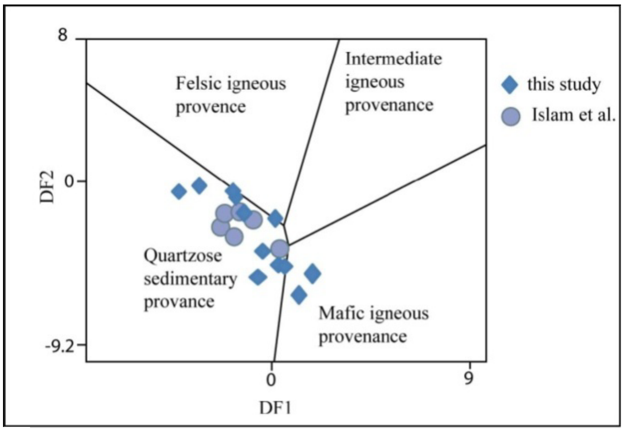


**Figure 7.** The discriminant function diagram for the provenance signatures of sandstone-mudstone suites using major elements after [37]

A discriminate function diagram (Fig. 7) has been proposed by Roser and Korsch [38] to distinguish between sediments whose provenance is primarily mafic, intermediate or felsic igneous and quartzose sedimentary. A plot of the first two discriminant functions based upon the oxides of Ti, Al, Fe, Mg, Ca, Na and K most effectively differentiates between the four provenances. The discriminate functions were calculated as-

Discriminant function 1 (DF1) = -1.773TiO2 + 0.607Al2O3+ 0.76Fe2O3 (total) -1.5MgO +0.616CaO +0.509Na2O - 1.224K2O - 9.09

Discriminant function 2 (DF2) = 0.445TiO2 + 0.07Al2O3 - 0.25Fe2O3 (total) 1.142MgO + 0.438CaO +1.47Na2O + 1.426K2O -6.861

The discriminant function diagram for the provenance analysis indicates that the Surma Group of sediments is deposited under quartzose sedimentary provenance and good agreement with previous analysis [30]. Quartzose sedimentary rocks are usually composed of silicate minerals and rock fragments that were transported by moving fluids (as bed load, suspended load, or by sediment gravity flows) and were deposited when these fluids came to rest.

## 5. Conclusions

In the present study there are twelve rock samples from different depth were analyzed. Geochemical of the rock samples revealed the rock type, depositional setting, sedimentation, and tectonics of the reservoir rock formation. Geochemical study indicates that the rock samples are enriching of quartz with a significant amount of aluminium oxide. Most of the samples are grayacke to litharenite in composition with the richness of quartz. Geochemical results are indicative for active continental margin deposition of the sediment under quartzose sedimentary provenance. However, the present result is comparable to previous studies of the Surma Basin.

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