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Case Study

Sedimentological, Geochemical and Hydrogeochemical Studies of Alluvial Fans for Mineral and Environmental Purposes (Case Study of Southwestern Iran)

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ABSTRACT

The alluvial-fan sediments play a very important and key role in mineral reserves and underground water resources, though a comprehensive study on such sediments, especially from a geochemical point of view, is still lacking. In this research, a total of 22 particularly important alluvial fans across the Khuzestan Plain in the southwestern Iran were studied through field surveys, petrographic evaluations, and geochemical assessments. These investigations included particle size distribution studies, microscopic observation of 193 samples, subsurface study of 60 boreholes along 10 different sections, facies analysis on 46 different sections, and comprehensive geochemical studies through XRD, XRF, ICP Mass, and wet chemical analyses. Based on these studies, the sediments were found to be dominantly composed of gravel, muddy sand, silt, and clay. The sediments exhibited good roundness and good to fair sorting. The most important facies observed in this study included Gmm, Gcm, Gh, Gmg, Gci, Sm, Sh, Fm, and Fi, with the most abundant oxide in the study area being Mgo followed by SiO_2 , $Al2O_3$ and $Fe2O_3$.

According to the studies, most of the samples fell in the range of iron-bearing sandstone, with rare cases of iron-bearing shales. Investigation of the geochemical indices showed the long sediment transport path from the source, humid weather and moderate to extensive weathering of the deposit. The deposition environment was found to be dominantly an active continental margin and, to a lesser extent, a continental island arc. Investigating into the source of the studied sediments indicate a felsic to slightly basic source rock. The environmental studies were indicative of relatively low contamination of the region and abundance of rare earth elements including Y, Sc, Nd, La, and Ce, and the abundance of heavy elements including Cr, Zn, Pb, and Cd. Based on the mineralogical studies on the samples, the inter-grain cement between the gravel and conglomerate particles was found to be composed of calcite.

Keywords: Geochemical studies; XRD; XRF; ICP Mass; Dezful

INTRODUCTION

Geological setting of the study area

The study area is part of The Zagros fold - thrust belt (Zagros FTB) in southwestern Iran. The Zagros fold-thrust belt in Iran forms the external part of the Zagros active orogenic wedge. This study area is located within 10 km of Dezfu, southwestern Iran. The sedimets have been developed in between the Bakhtiari Formation and Khuzestan Plain (Figure 1).

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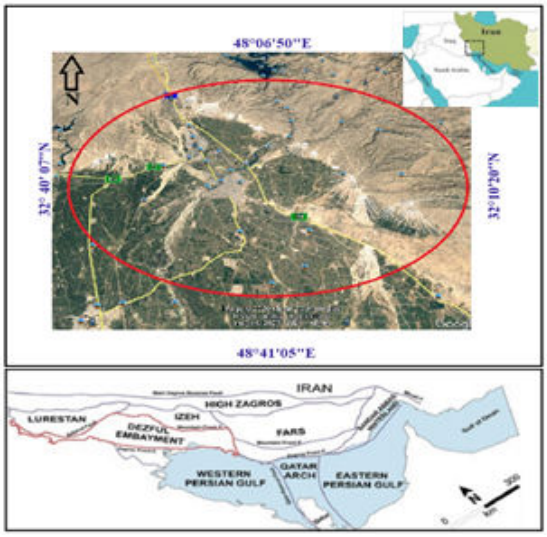

Figure 1: The Study Area location in the Zagros Orogenic Belt (Southwest of Iran).

Nowadays, there are many studies on the geochemistry of detrital rocks to determine the provenance of sediments; among which fundamental studies on the parent rock tectonic status climate and chemical weathering can be considered. These studies attempt to provide a complete perspective on the geochemical studies of this sediment by conducting case studies on the detrital sediment of 22 main alluvial fans in southwestern Iran [1].

In the first part, field and petrographic studies were performed to verify and correlate with geochemical data. After field sampling, particle size was determined and named. The results of drilling logs of 60 wells were also evaluated to determine the exact lithology of the area. For geochemical studies, 68 samples of 22 alluvial fans in the region were selected for XRD (X-Ray Diffraction), XRF (X-Ray Fluorescence) and ICP Mass (Inductively coupled plasma mass spectrometry) studies. Also, due to being a residential area, to investigate the groundwater quality under these alluvial fans, 40 samples were taken for the wet chemistry studies (Figure 2)[2].

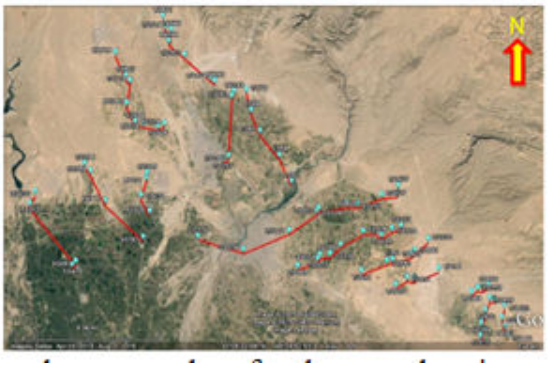

Figure 2: The location of the Sampled Places in Alluvial Fans of Dezful.

Alluvial fans are cone-shaped sediment that are formed the borders of the mountains; they decrease the thickness and enhance the area in more distances by approaching the plain. Alluvial fans are composed of boulder, gravel, sand, silt and clay sediment. Because of their high economic importance, especially as important groundwater resources and the presence of gold placers, investigating this sediment is very important. The study area consists of 22 main alluvial fans that extend from the north of the Dezful County in southwestern Iran to the southeast of it. In these studies, the mentioned sediment originated from the Bakhtiari Clastic Formation that contains the conglomerate and sandstone lithology; they are studied in two different parts. In the first part, to verify and correlate with geochemical studies, sedimentology and field investigations are discussed and in the second part, the sediment are studied comprehensively.

FIELD AND LITHOLOGICAL STUDIES

Granulometry and field Studies

After field studies, the results of the granulometric experiments were plotted as a distribution curve grading, and after determining the percentage of grain size, it was turned out that the grain sizes range between gravel to clay. Lithologically, the studied alluvial fans consist of coarse-grained sediment at the apex, and the medial part of the dominant lithology is composed of course, medium to fine sand grains, and eventually, at the distal part, the dominant lithology ends with medium sand grain to silt and clay (Figure 3).

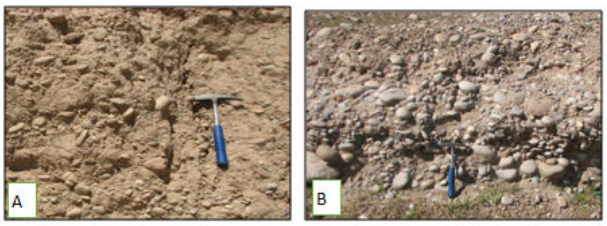

Figure 3: Macroscopic Image of the Sediment of the Study Area.

MICROSCOPIC STUDIES

To determine the accurate lithology of sediment and their relation with the provenance, 110 samples of conglomerate fragments of Bakhtiari Formation as source rocks, and as well, 83 samples of interbedded sandstones were sampled and studied under the microscope. Figure 4 shows a specimen of conglomerate fragments and a sample of interbedded sandstone fragments as examples. Figure A is a conglomerate with fossiliferous calcareous and dolomitic fragments that is well-rounded, well- to moderately sorted, and contains little cherty rock debris and radiolarite. Figure B is the interbedded sediment containing lithic sandstones accompanied with micritic and fossiliferous limestone debris, little cherty debris, monocrystalline quartz minerals with direct extinction, radiolarite debris, rarely plagioclase feldspar minerals; there are also some pressure-induced indented contacts with vuggy porosity and calcareous to slightly ferrous cement. It should be noted that the results of the study of other microscopic sections indicated very similar results to those presented. The microscopic study of the sediment is consistent with the geochemical results presented in the following sections and shows that the sediment is calcareous [3-7].

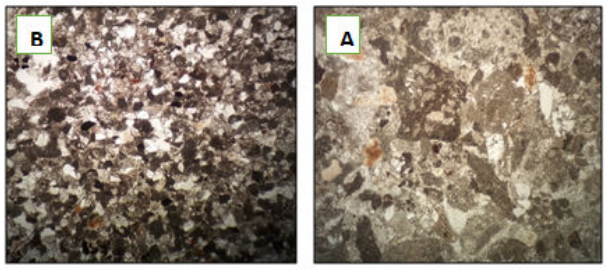

Figure 4: Microscopic Image of Bakhtiari Formation sediment (Source Rock of Studied Sediments) at 25 Magnification.

FUNDAMENTAL STUDIES

Analysis of oxides

To study the provenance of sediments, the oxide percentage of Si, Al, Mg, Ca, Mn, Na, K, P, Si is used. To study the oxides in the study samples, 68 samples from different parts of the Dezful area were evaluated by XRF and ICP-MASS methods, focusing on distal parts [8-11].

Sample No	S.2	S.8	S.14	S.20	S.33	S.41	S.48	S.53	S.60	S.67
Formula	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
SiO_2	28	28.528	18.866	14.417	19.275	26.771	23.988	23.81	32.129	27.315
Al_2O_3	3.277	1.842	3.906	2.545	2.755	6.892	3.785	6.062	8.368	6.632
Fe_2O_3	3.031	2.393	3.25	2.066	2.395	4.691	3.286	4.332	6.505	4.171
CaO	37.928	40.938	43.519	46.826	43.635	31.46	40.137	32.929	24.031	32.878
MgO	1.344	0.854	1.695	1.497	2.048	2.889	2.549	3.641	3.831	2.928
Na_2O	0.75	0.75	0.75	0.75	0.75	0.273	0.75	0.329	0.75	0.399
K_2O	0.621	0.401	0.761	0.35	0.395	1.154	0.675	1.041	1.408	1.048
P_2O_5	0.75	0.75	0.75	0.75	0.75	0.106	0.111	0.118	0.117	0.113
SO_3	0.177	0.75	0.75	0.75	0.75	0.75	0.75	0.158	0.75	0.75
TiO_2	0.361	0.309	0.351	0.265	0.288	0.636	0.295	0.571	0.884	0.598
SrO	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Cl	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75

Table 1: The results of XRF elemental analysis of some samples of the Dezful area.

CONCLUSION

The conducted studies provided extensive results on the detrital sediment of the area, which are summarized in the following section:

Based on petrographic, field and subsurface studies, the mentioned area is composed of 22 main alluvial fans. The dominant lithologies of these sediment include gravels, sandy gravels, muddy sands, silt and clay, and are well-rounded and well- to moderately sorted. Based on these investigations, the dominant lithology of the source area is also carbonate conglomerates.

The most important facies observed in the study area are coarse-grained facies (Gmm, Gcm, Gh, Gmg, Gci), medium-grained facies (Sm, Sh) and fine-grained facies (Fm, Fi). The repetition of these facies in different parts of the study area indicates the existence of alternating river flows in those parts accompanied by the presence of debris flows, especially in the southeastern parts of the Dezful. The results of studying these facies not only are important for mineral consumption and especially road construction but also are consistent with the geochemical results obtained from the origin and paleoclimatic conditions, indicating the humid climate and moderate weathering of the sediments.

Chemical analysis of the major elements in these sediment shows that the most abundant oxides in the area are MgO, SiO_2, Al_2O_3, and Fe_2O_3, respectively. Also, the percentages of other oxides such as MgO, Na_2O, K_2O, and P_2O_5 are very low.

The average SiO_2 content in the study area is higher than the upper crust, indicating relatively high maturity of sedimentary rocks in this area. Besides, the average amount of Al_2O_3 these are sediment in this area is lower than this value in the upper crust, which is probably due to the presence of debris and carbonate cements in these sediments; the presence of them increases the CaO percentage and decrease the SiO_2 proportion partially.

Dramatic decrease of Fe_2O_3 and MgO in the study area will be the concerning the upper crust indicates the absence or presence of a low proportion of mafic minerals in the sediment of the area or is because of the low quantity of diagenetic cements of dolomite and hematite. Furthermore, the very low percentage of K_2O and Na_2O indicates the origin of these elements from the plagioclases dissolution.

Due to the presence of clay minerals, mica, feldspars as well as appropriate sedimentary maturity, the Al_2O_3 variations in any of accompanied by Fe_2O_3, K_2O, MgO, SiO_2, TiO_2 shown limited positive trend, while demonstrating negative trend with CaO.

According to studies, most samples are in the ferrous sandstone limit and rarely in the ferrous shale area; these samples are also Arkosic.

The study of different weathering indices shows a long distance of sediment replacement from the source to the deposition area, humid climate and moderate to severe weathering. These results are also confirmed by petrographic and facies studies.

Studies show that sediment in the study area are mainly related to continental active margin and to a lesser extent to the continental island arc.

The origin of these sediment indicates a felsic to slightly basic source rock.

The study of rare and heavy elements due to their importance in the mining sector represents the abundance of rare earth elements in descending order, including Y, Sc, Nd, La, Ce. As well, the most abundant heavy elements in the study area are cr, zn, pb, and cd, respectively.

Environmental studies which are important due to the residential and agricultural areas indicate relatively low contamination in the area, based on different indices, especially in terms of heavy metals.

Based on mineralogical studies, the cement type between gravel and conglomerate fragments is of calcite type and is the main phase in XRD results. In addition to calcite, quartz, feldspar, and dolomite and in some samples gypsum are the main phase minerals which are present in the Dezful area. These results are consistent with petrographic and facies results and play an important role in their mineral use, especially in road construction.

The results of the wet chemistry of groundwater for their quality assessment in the study area show a direct relationship between provenance sediment and the aquifer sediment with groundwater quality in the area. Based on these studies, by increasing calcite content in sediment, the increased proportion of it can be seen in the water samples of the area. Also, the low percentage of calcium and magnesium in these sediment is considerably accompanied with moderate to low water hardness. In addition, the low EC content corresponds to the low salt concentration of sediment in the same area. Eventually, the low quantity of sodium and potassium is quite consistent with the low amount of them in water samples. These investigations not only confirm the drinking and agricultural uses of these samples but also represent a new way of studying the water samples of the area, applying sediment samples in places where groundwater is not available.

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