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Geochemical and Hydrochemical Assessment of Clastic Sediments in Southwestern Iran: A Case Study of Deposits in the Omidiyeh Region, Khuzestan Province

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Abstract

This study provides a comprehensive geochemical and hydrochemical analysis of alluvial fan sediments in the Omidiyeh region, Khuzestan Province, southwestern Iran. Alluvial fans, formed at the base of mountains, are crucial for groundwater accumulation and mineral resource extraction. In this research, 120 sediment samples from various alluvial fan locations were collected and analyzed for their petrographic and geochemical properties. Petrographic analysis revealed that the sediments are predominantly composed of quartz, feldspar, and lithic fragments, classifying them as lithoarenites. Geochemical investigations identified calcium oxide (CaO), silicon dioxide (SiO2), and magnesium oxide (MgO) as the most abundant oxides in the samples. Rare earth elements such as neodymium (Nd), yttrium (Y), lanthanum (La), and cerium (Ce) were found in significant concentrations. Additionally, the study explored the correlation between aluminum oxide (Al2O3) and other oxides, showing positive relationships with iron oxide (Fe2O3), potassium oxide (K2O), magnesium oxide (MgO), and titanium dioxide (TiO2), suggesting an association with phyllosilicates and heavy minerals. Hydrochemical analysis of groundwater in the region revealed elevated levels of chlorine (Cl), nickel (Ni), calcium (Ca), and magnesium (Mg), indicating potential contamination from oil pollution and geological sources. The study also highlighted concerns over water hardness and dissolved salts, attributed to industrial and agricultural activities. Overall, this research enhances our understanding of alluvial fan dynamics and provides valuable insights for environmental, mineralogical, agricultural, and urban risk assessments. The findings offer a model for similar studies worldwide, helping to address environmental and resource management challenges in comparable regions.

Keywords: Alluvial fans, Geochemical analysis, Hydrochemical analysis, Khuzestan Province, Heavy minerals, Omidiyeh region

1. INTRODUCTION

Alluvial fans are distinctive sedimentary landforms shaped like cones or funnels that form at the confluence of mountainous and flat terrains (Tavanaei et al., 2020). These formations arise as rivers or streams carrying sediment from mountainous areas spread out and deposit their loads when they encounter flatter ground (Bowman, 2019). The shape and size of alluvial fans change notably as one transitions from the steeper, more mountainous regions to the gentler, flatter plains(Zhang et al., 2019). Specifically, the fans typically exhibit a decrease in thickness and an increase in width as they extend from their source areas (Mazzorana et al., 2020).From an economic standpoint, understanding alluvial fan sediments is critically important (Zhang et al., 2019). These formations often serve as key areas for groundwater recharge, with many underground aquifers in sedimentary basins being replenished by water that infiltrates through these fan deposits (Zhang et al., 2019). As such, alluvial fans play a vital role in maintaining water resources in arid and semi-arid regions. Additionally, these sediments are significant for their mineral content. For example, ancient alluvial fan deposits in South Africa are renowned for their rich placer gold deposits, which have been a major source of gold extraction globally (Ahmad et al., 2020). Similarly, placer uranium is also extracted from these sedimentary deposits, highlighting the economic value of alluvial fans in mineral extraction (Pourmorad and Mohanty, 2022).anty, 2022).

The present study focuses on the geological, geochemical, and morphotectonic characteristics of alluvial fans located in southwestern Iran, particularly in the vicinity of Omidiyeh City. By examining the sedimentary structures, mineral composition, and geochemical signatures of these alluvial fans, this research aims to provide a detailed understanding of their formation and distribution.

The study aims to achieve several objectives through a multi-faceted approach. First, it seeks to conduct a geological analysis to explore the sedimentary processes and geological formations associated with alluvial fans. This involves assessing the depositional environments and understanding the factors that influence sediment distribution. Second, the research will undertake a geochemical profiling of the sediments, analyzing their chemical composition to identify key elements and minerals. This analysis will focus on major, minor, and trace elements to gain insights into the sediment's origin and potential resource value. Third, the study will perform a morphotectonic assessment to evaluate the structural and tectonic settings that affect the development and morphology of alluvial fans, including the impact of tectonic activity on sediment deposition and fan shape. The anticipated outcomes of this research are expected to significantly advance our understanding of alluvial fan dynamics and their environmental implications. The insights gained will be valuable for several key areas. For environmental management, the study will provide data to help manage water resources and mitigate potential environmental hazards related to sedimentary processes. In the field of mineralogical studies, detailed data on sediment composition will guide the exploration and extraction of valuable resources. For agricultural planning, the research will offer information on how sediment properties influence soil quality and groundwater availability, thereby informing better agricultural practices. Additionally, the findings will assist in urban risk assessment by evaluating and mitigating risks associated with urban development in areas influenced by alluvial fan sedimentation.Overall, this research is poised to make significant contributions to the fields of geology, hydrology, and environmental science. By providing a comprehensive analysis of alluvial fan systems in southwestern Iran, the study will offer valuable benchmarks for similar investigations in other regions, supporting global efforts to manage and utilize sedimentary resources effectively.

2. GEOGRAPHICAL POSITION

The area under investigation lies in the southwestern region of Iran, specifically within Khuzestan Province, approximately 5 kilometers southeast of Omidiyeh. Its geographical coordinates range from 49 degrees, 43 minutes, and 57 seconds to 49 degrees, 45 minutes, and 3 seconds east longitude, and 30 degrees, 45 minutes, and 7 seconds to 30 degrees, 43 minutes, and 25 seconds north latitude from the equator. The focal point of study, known as the Omidiyeh cinder cone, is an expansive and pr ototypical cinder cone, stretching over 25 kilometers in length and 10 kilometers in width (See Figure 1).Additionally, the specific coordinates for two points within the study area are as follows:

- **Point A**: 49° 43′ 50″ E, 30° 45′ 00″ N
- **Point B**: 49° 43′ 49″ E, 30° 44′ 52″ N

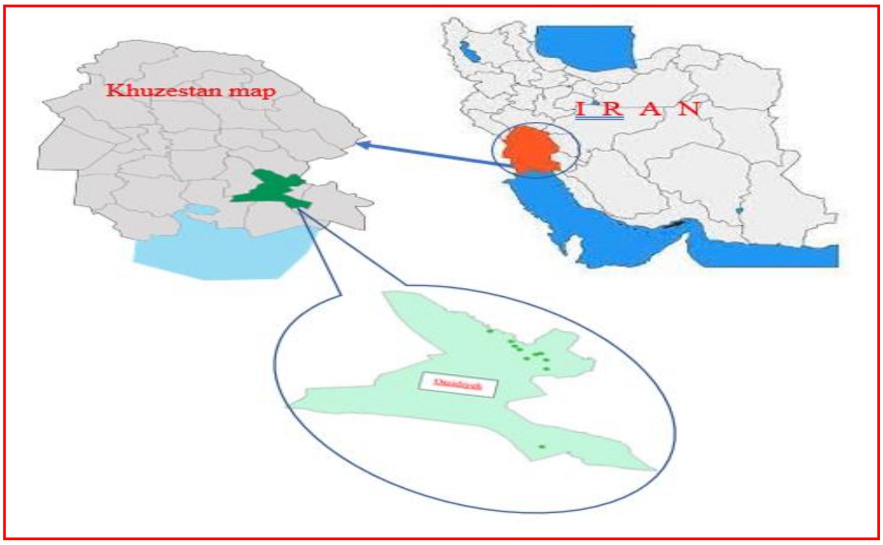


Fig. 1. Geographical location of the studied area

3. METHODOLOGY OF INVESTIGATION

To conduct this study, initial desk research was undertaken, which involved reviewing numerous articles and books. Subsequently, preliminary geological investigations of the designated area were conducted, encompassing tectonic and petrological analyses. Following a comprehensive understanding of the geological attributes of the region, random sampling was executed in accordance with established sampling protocols. During this phase of the research, a total of 120 soil samples were collected from various sections of the alluvial cones within the area (extracted from the base of watercourses). In the collection of these soil samples, efforts were made to obtain samples from upstream (proximal), midstream (medial), and downstream (distal) segments of the alluvial terrain, ensuring a comprehensive representation of the geological and environmental characteristics of the locale. The samples earmarked for mineralogical and geochemical investigations were dispatched to the geochemical laboratories of the Geological Organization of Iran subsequent to classification and documentation of primary sedimentary traits. Utilizing XRD, XRF, and ICP Mass spectrometry devices, these laboratories facilitated the determination of oxides, minerals, and rare earth elements. Additionally, four samples of subterranean water were gathered from the area to assess its quality, and these samples underwent thorough analysis and scrutiny by the Geological Organization of Iran.

4. DISCUSSION AND CRITICAL REVIEW

This section delves into the examination of petrographic findings, followed by the assessment of geochemical data, culminating in a thorough interpretation of the pertinent results.

4.1. Petrographic Analysis.

Petrographic examinations provide critical insights into the sedimentary attributes, origins, and composition of the specimens being analyzed. According to the findings, petrographic analysis of the samples from the study area reveals that the predominant constituents are rock fragments, including chert, limestone, sand, and igneous rock fragments, which together make up approximately 83% of the siliceous sediments. These sediments fall within the litho-arenite petrofacies, characterized by their siliceous nature.

The sedimentary grains in the study area predominantly exhibit well-to-moderately well-rounded profiles, embedded within a calcareous matrix. This observation is supported by the detailed petrographic images (Figure 2a) showing the overall grain characteristics. As one moves towards the apex of the alluvial fan, the sediments display improved granular attributes, with grains showing semi-angular forms (Figure 2b). The sediment particles range from semi-angular to semi-rounded, with various contact types including point, linear, and convex-concave (Figures 2c and d).

Additionally, the analysis indicates that potassium feldspar is more prevalent than plagioclase in the sediment samples. Microscopic examination reveals that feldspars exhibit varying degrees of weathering across different areas of the study region (Figure 2e). This variability in weathering is an important factor in understanding the sediment's formation and alteration processes.

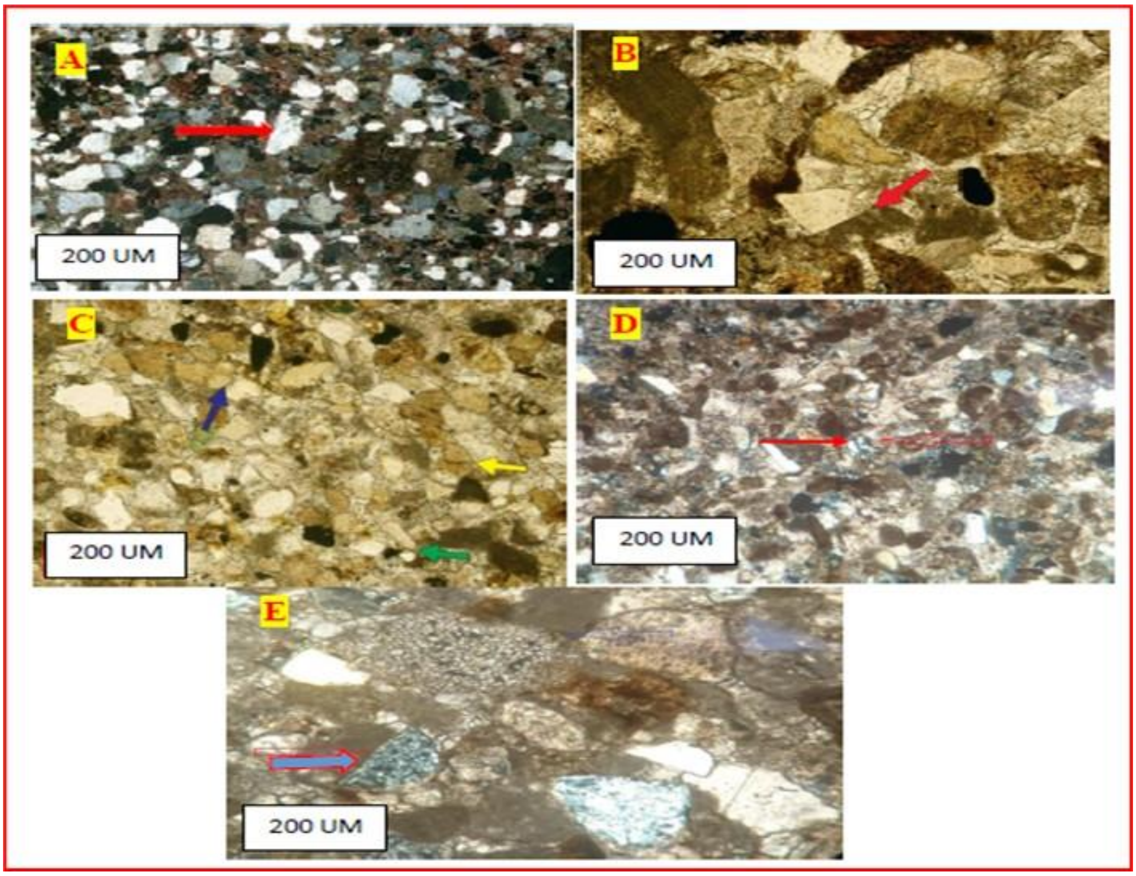


Fig. 2. Microscopic Examination of Particle Composition and Sedimentary Rocks in Upstream

Formations of the Study Area. a) Microscopic view of coarse particles within coarse sandstones exhibiting semi-angular to rounded grains and semi-rounded grains with good to moderate sphericity. b) Observation of convex and concave point contacts of gravels and small stones within the Bakhtiari Formation. c) Microscopic depiction of point contacts (green arrow), linear contacts (blue arrow), and convex and concave contacts (yellow arrow) in litho-arenite type sandstonewithin the Aghajari Formation. d) Examination of semi-angular to semi-rounded sand grains with moderate rounding and polycrystalline quartz content (red arrow) within the Gachsaran Formation. e) Observation of chert (red arrow) and calcite cement (blue arrow) alongside quartz grains exhibiting direct wave extinction within the Aghajari Formation.

Given the dominance of quartz, feldspar, and lithic fragments in the analyzed samples, these sediments are classified within the litho-arenite category according to Folk's classification scheme (1980) (Figure 3). This classification helps to contextualize the sedimentary characteristics and their implications for the geological history and sedimentary environment of the area. Overall, the petrographic analysis provides a detailed understanding of the sediment's composition and its geological significance within the studied alluvial fan system.

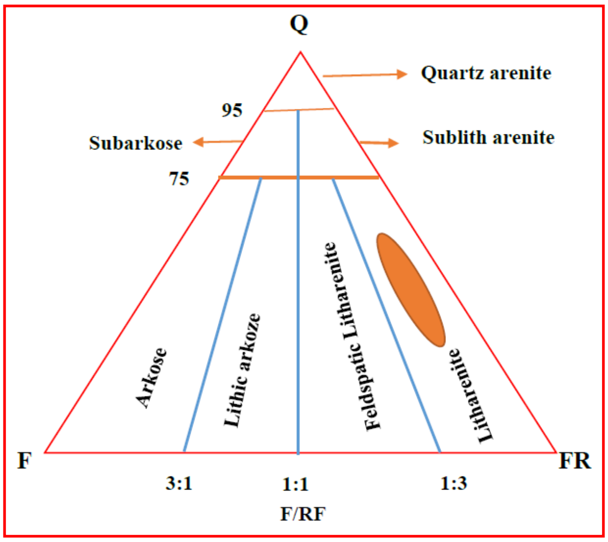


Fig. 3. Spatial Distribution of Sample Data Classified According to Folk's (1980) Litharenite Model, Indicating Predominantly Lite-Arenite Composition.

4.2. Geochemical Investigations.

For the execution of these investigations, a total of 120 samples (across 2 designated study zones) were procured from the Omidiye locale and subsequently subjected to mineralogical (XRD), elemental (XRF), and mass spectrometry (ICP-MS) analyses at the Geological Laboratory of Iran. Additionally, four water samples sourced from agricultural wells within the region underwent comprehensive chemical and physical assessments to ascertain their elemental composition, quality, and their impact on agricultural terrains and crops, alongside hydrochemical appraisals in these environs.

4.3. Analysis of Oxides

In analyzing the sedimentary samples from the Omidiye region, oxides play a crucial role in understanding the geochemical properties and formation conditions of the sediments. The examination of these oxides provides insights into the dominant chemical components and their implications for the sedimentary environment. Among the critical oxides assessed, calcium oxide (CaO) and silica oxide (SiO2) are the most prevalent in the sediment samples from the Omidiye region. Calcium oxide, a major component in many sedimentary rocks, often results from the weathering of limestone and other calcareous materials. Its high concentration in the samples suggests a significant presence of calcareous fragments or the influence of calcareous sedimentary processes in the area.Silica oxide, commonly found in quartz and silicate minerals, also ranks highly among the oxides. The prevalence of SiO2 indicates a substantial amount of quartz or siliceous material within the sediments. This aligns with the observation that the sediments are rich in siliceous components, contributing to their classification as litho-arenite petrofacies. Conversely, other oxides such as sodium oxide (Na2O), phosphorus pentoxide (P2O5), strontium oxide (SrO), titanium dioxide (TiO2), and potassium oxide (K2O) are present in lower abundances within the sediment samples. Sodium oxide and potassium oxide are typically derived from feldspar and other alkali minerals. The lower levels of these oxides suggest that feldspar and similar minerals are less abundant in the sedimentary matrix.Phosphorus pentoxide, which is often associated with phosphatic minerals and organic matter, is found in minimal quantities. Its low concentration implies that phosphatic materials are scarce in the sedimentary deposits of this region. Strontium oxide and titanium dioxide, both of which are commonly associated with accessory minerals, such as rutile and zircon, also register as less abundant. The low levels of these oxides may indicate a reduced presence of such minerals in the sedimentary environment. The analysis outcomes are detailed in Table 1 and graphically represented in Figure 4, which illustrates the relative abundances of these oxides within the study zone. The graphical representation aids in visualizing the concentration trends and comparing the proportions of various oxides across the samples.

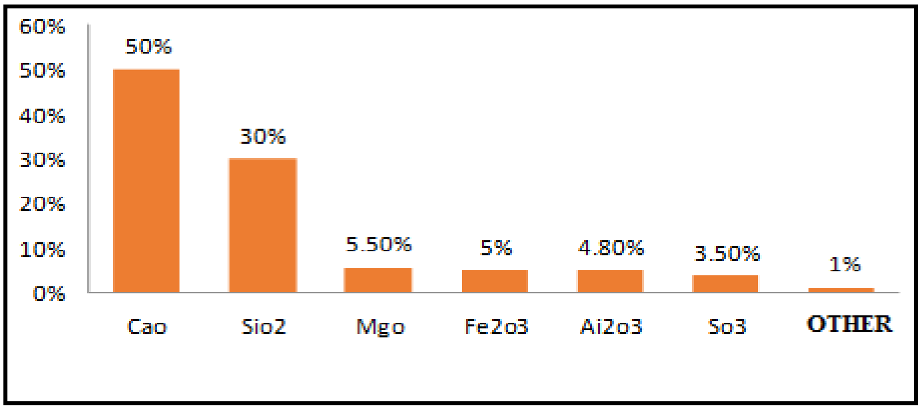


Fig. 4. Comparative Column Chart Illustrating Oxide and Elemental Composition Averages across Study Samples

Table 1. Mean Composition of Oxides and Elements in Sample Data

Na2O, P2O5, SrO, TiO2, K2O	So_3	Fe_20_3	Al_2o_3	Mgo	Sio_2	Cao	Oxides
1	3.5	5	4.8	5.50	30.2	50	Percnt

Overall, the predominance of CaO and SiO2 in the sediment samples underscores the influence of calcareous and siliceous processes in the sedimentary environment. The lower abundances of other oxides highlight the specific mineralogical and geochemical characteristics of the sediments in the Omidiye region. Understanding these oxide distributions provides valuable information for interpreting the sedimentary processes and environmental conditions that shaped these deposits.

4.4. Minor Elements .

The analysis of minor elements within the sedimentary samples from the surveyed regions provides valuable insights into the geochemical composition and mineralogical characteristics of the sediments. Among the minor elements identified, titanium (Ti) emerges as the most predominant.

- Titanium (Ti): Titanium is found in the highest concentration across the study area, with an average of 1451 parts per million (ppm). This substantial presence of titanium suggests that the sediments are enriched in titanium-bearing minerals, such as ilmenite and rutile. Titanium's high concentration can be indicative of the geological processes that led to the accumulation of these minerals, including the influence of igneous and metamorphic source rocks.

- Zirconium (Zr): Following titanium, zirconium is the next most abundant minor element, with an average concentration of 72.8 ppm. Zirconium is commonly associated with the mineral zircon (ZrSiO4), which is a stable and resistant mineral found in many sedimentary environments.zircon (ZrSiO4), which is a stable and resistant mineral found in many sedimentary environments. The relatively high levels of zirconium point to the presence of zircon-rich minerals in the sediment, which may be derived from both igneous and metamorphic sources.

- Vanadium (V): Vanadium is present at an average concentration of 45.6 ppm. This element is often found in association with other minor elements such as titanium and zirconium in various minerals. Vanadium's presence can provide additional clues about the sediment's mineralogical composition and its source rocks.

-Cerium (Ce): Cerium, with an average concentration of 21.2 ppm, is one of the rare earth elements detected in the sediments. As a major light rare earth element, cerium is typically associated with minerals like monazite and bastnaesite. Its presence in the sediments suggests the influence of rare earth mineral sources in the sedimentary system.

- Lanthanum (La): Lanthanum ranks fifth among the minor elements with an average concentration of 12.8 ppm. Lanthanum is another rare earth element often found alongside cerium in rare earth mineral deposits. Its occurrence in the sediments reinforces the presence of rare earth minerals and suggests the contribution of such minerals to the overall geochemical profile of the sediments.The distribution and concentration of these minor elements, as depicted in Figure 5, provide crucial insights into the sediment's mineralogical and geochemical characteristics. The high levels of titanium and zirconium suggest a significant presence of titanium-bearing and zircon-rich minerals, while the presence of vanadium, cerium, and lanthanum highlights the role of rare earth elements in the sedimentary environment. Understanding the concentration and distribution of these minor elements helps in interpreting the sedimentary processes and the geological history of the region. It also aids in assessing the potential economic value of the sediments, particularly with regard to the presence of valuable minerals and rare earth elements

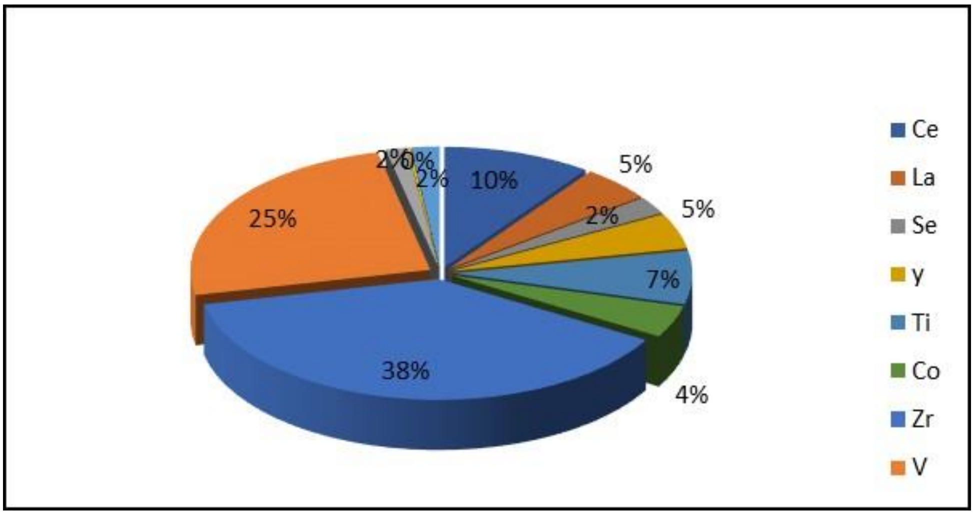


Fig. 5. Distribution of Secondary Element Abundance in Samples from the Investigated Region

4.5. Rare Earth Elements.

In the surveyed area, a comprehensive analysis of rare earth elements (REEs) reveals that cerium (Ce) is the most abundant, with an average concentration of 21.12 parts per million (ppm). This high concentration of cerium suggests that cerium-rich minerals, such as monazite or bastnaesite, are prevalent in the sediments. Cerium's dominance can offer insights into the mineralogical composition and potential economic value of the sediments.

Following cerium, lanthanum (La) ranks second with an average concentration of 12.4 ppm. Lanthanum, often found in conjunction with cerium, indicates the presence of similar mineral sources.

The presence of lanthanum alongside cerium is significant, as it supports the interpretation of a shared geochemical origin for these elements.

Yttrium (Y) and neodymium (Nd) are the next most prevalent REEs, with average concentrations of 9.11 ppm and 9.3 ppm, respectively. The notable presence of yttrium and neodymium suggests that these elements contribute substantially to the overall REE profile of the sediments. Yttrium is often associated with minerals such as xenotime, while neodymium is commonly found in minerals like monazite and bastnaesite.

Scandium (Sc) is present at an average concentration of 4.7 ppm, with praseodymium (Pr) following at 2.76 ppm. Although less abundant, scandium and praseodymium play a role in defining the REE characteristics of the sediments.Samarium (Sm),gadolinium(Gd), and dysprosium (Dy) are present at lower concentrations, averaging 2.06 ppm, 1.8 ppm, and 1.56 ppm, respectively. These elements, though less prominent, contribute to the overall REE diversity and are essential for a complete geochemical profile.In the context of oxides, calcium oxide (CaO) and silicon dioxide (SiO2) are identified as the most prevalent components in the sediments. The dominance of these oxides indicates a consistent sedimentary maturity across the study area. High levels of CaO and SiO2 reflect the sediment's advanced stage of weathering and sorting, suggesting a stable geochemical environment (Figure 6)

The analysis shows that fluctuations in CaO concentrations generally correspond with variations in SiO2 levels across the region. This correlation suggests a uniform depositional environment. However, in certain localized areas, an inverse relationship is observed between CaO and SiO2 concentrations. This discrepancy can be attributed to the presence of small stones within the sediments. These stones contribute to an increase in CaO percentages while causing a relative decrease in SiO2 levels.

The inverse correlation between CaO and SiO2 in specific regions implies variations in sediment composition and depositional processes. This phenomenon highlights the role of lithological diversity in influencing the overall chemical composition of the sediments. Such variations provide valuable insights into the depositional environment and can assist in interpreting the geological history of the area.

The detailed geochemical analysis of REEs and oxides in the surveyed sediments offers a comprehensive view of the mineralogical and chemical characteristics of the area. The high concentrations of cerium and lanthanum, along with the presence of other REEs, underscore the significance of these elements in understanding the sediment's geochemical profile.

The observed trends and correlations in oxide concentrations further enhance our understanding of sedimentary processes and environmental conditions. This analysis not only contributes to the knowledge of sedimentary geology but also provides valuable data for future exploration and resource assessment.

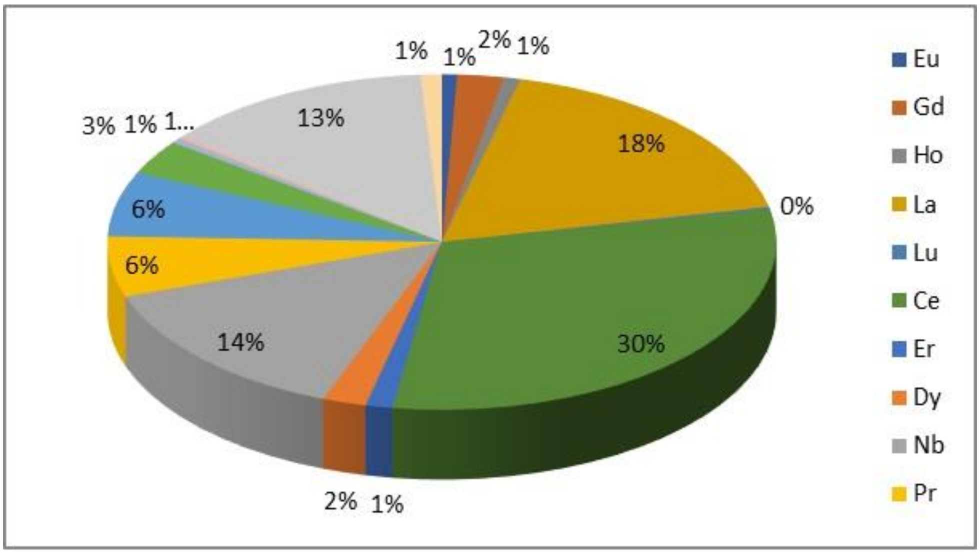


Fig. 6. Mean Abundance of Rare Earth Elements in the Examined Regions (ppm).

4.6. Analysis of Key Elements Using the Aluminum Scale.

Aluminum oxide (Al_2O_3) demonstrates notable stability in natural environments. Its concentration typically increases during wet weather and decreases in dry conditions, reflecting its response to environmental moisture variations (Pourmorad et al., 2021). This stability renders aluminum oxide a crucial element for understanding primary constituents in detrital sediments, as it remains relatively constant throughout diagenesis, weathering, and metamorphism (Smirnov et al., 2019; Sahraeyan and Bahrami, 2016). Consequently, aluminum oxide serves as a key indicator in sedimentological studies, offering insights into sedimentary processes and the geochemical history of the studied region.

In the surveyed region, the concentration of aluminum oxide exhibits a positive correlation with several other oxides, including iron oxide (Fe_2O_3), potassium oxide (K_2O), magnesium oxide (MgO), and titanium dioxide (TiO_2). This suggests that as aluminum oxide levels increase, so do the levels of these associated oxides. Conversely, aluminum oxide shows a negative correlation with calcium oxide (CaO), indicating that as the concentration of aluminum oxide rises, calcium oxide levels tend to decrease (Figure 7).

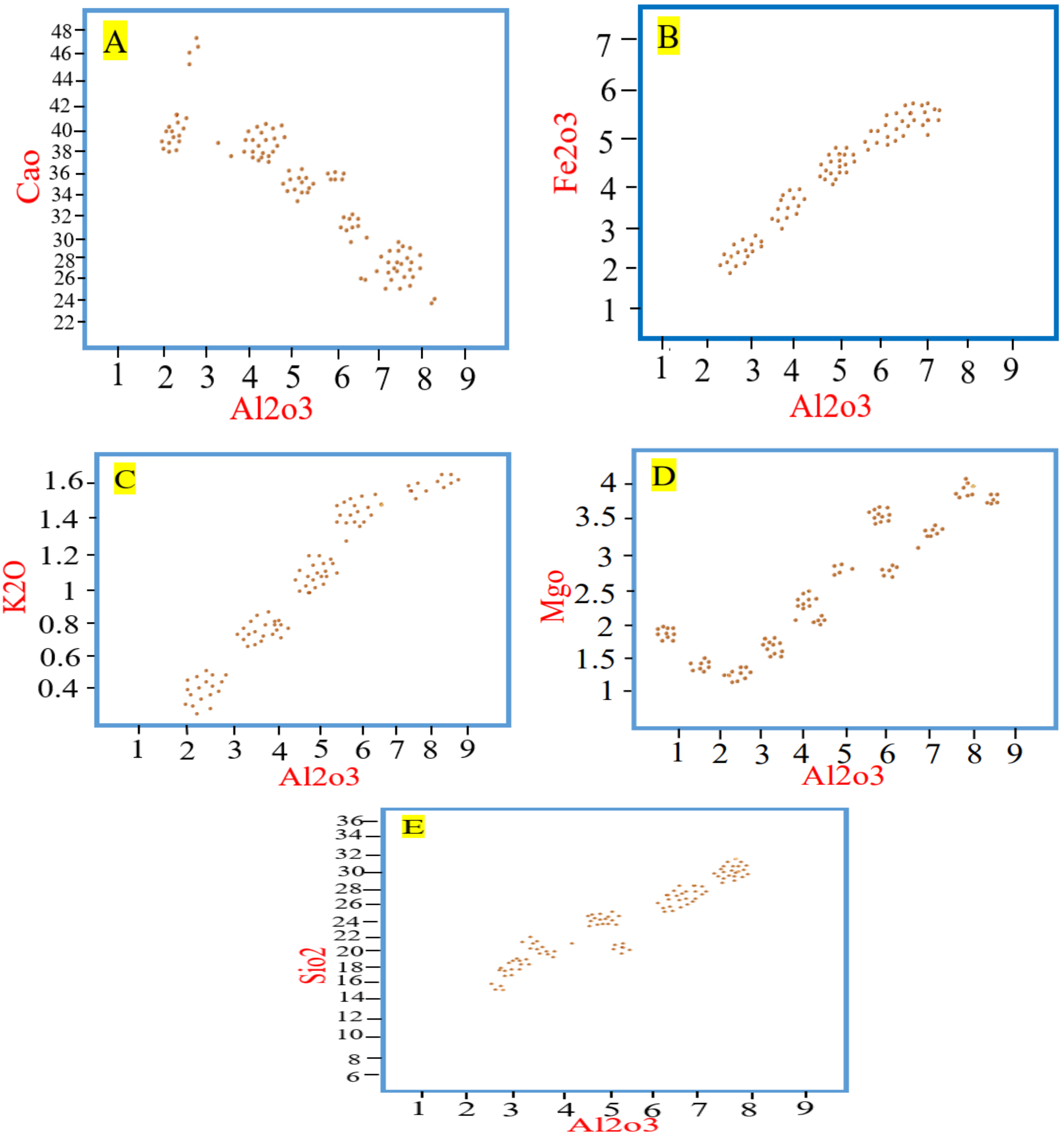


Fig. 7. Analysis of Main Oxides Relative to Aluminum Oxide. a) Demonstrating a negative correlation between Al2O3 and CaO, b) Illustrating a positive correlation between Al2O3 and Fe2O3, c) Depicting a positive correlation between Al2O3 and K2O, d) Showing a positive correlation between Al2O3 and MgO, e) Highlighting a positive correlation between Al2O3 and SiO2.

A closer examination of the relationship between titanium dioxide (TiO_2) and aluminum oxide (Al_2O_3) reveals a positive correlation (Figure 8a). This association is significant because titanium is often concentrated in phyllosilicate minerals, which are relatively immobile during sedimentary processes. As such, high titanium concentrations can be indicative of the presence of these minerals and can help in interpreting source rock characteristics (Sharma et al., 2020). The concurrent increase of Al_2O_3 with TiO_2 reinforces the notion that both oxides are associated with phyllosilicates in the region.

Further analysis of the relationships between titanium oxide and minor elements such as vanadium (V) and chromium (Cr) reveals positive correlations (Figures 8b and c). This finding underscores the association of titanium with these elements, suggesting the presence of heavy minerals in the surveyed sediments. Vanadium and chromium are frequently linked with iron and titanium in heavy minerals, such as those found in sedimentary deposits (Al-Hashim and Corcoran, 2020). The presence of these heavy minerals provides valuable insights into the mineralogical composition of the sediments and the potential economic significance of the region.

The analysis of aluminum oxide, titanium dioxide, and associated minor elements reveals important geochemical relationships within the surveyed sediments. The stability of aluminum oxide, combined with its positive correlations with Fe_2O_3, K_2O, MgO, TiO_2, and minor elements such as V and Cr, highlights its role as a fundamental indicator of sedimentary processes. The positive correlation between Al_2O_3 and TiO_2, along with the association of TiO_2 with V and Cr, underscores the presence of phyllosilicates and heavy minerals in the sediments. These findings contribute to a deeper understanding of the sedimentary environment and offer valuable insights into the geological and economic aspects of the study area.

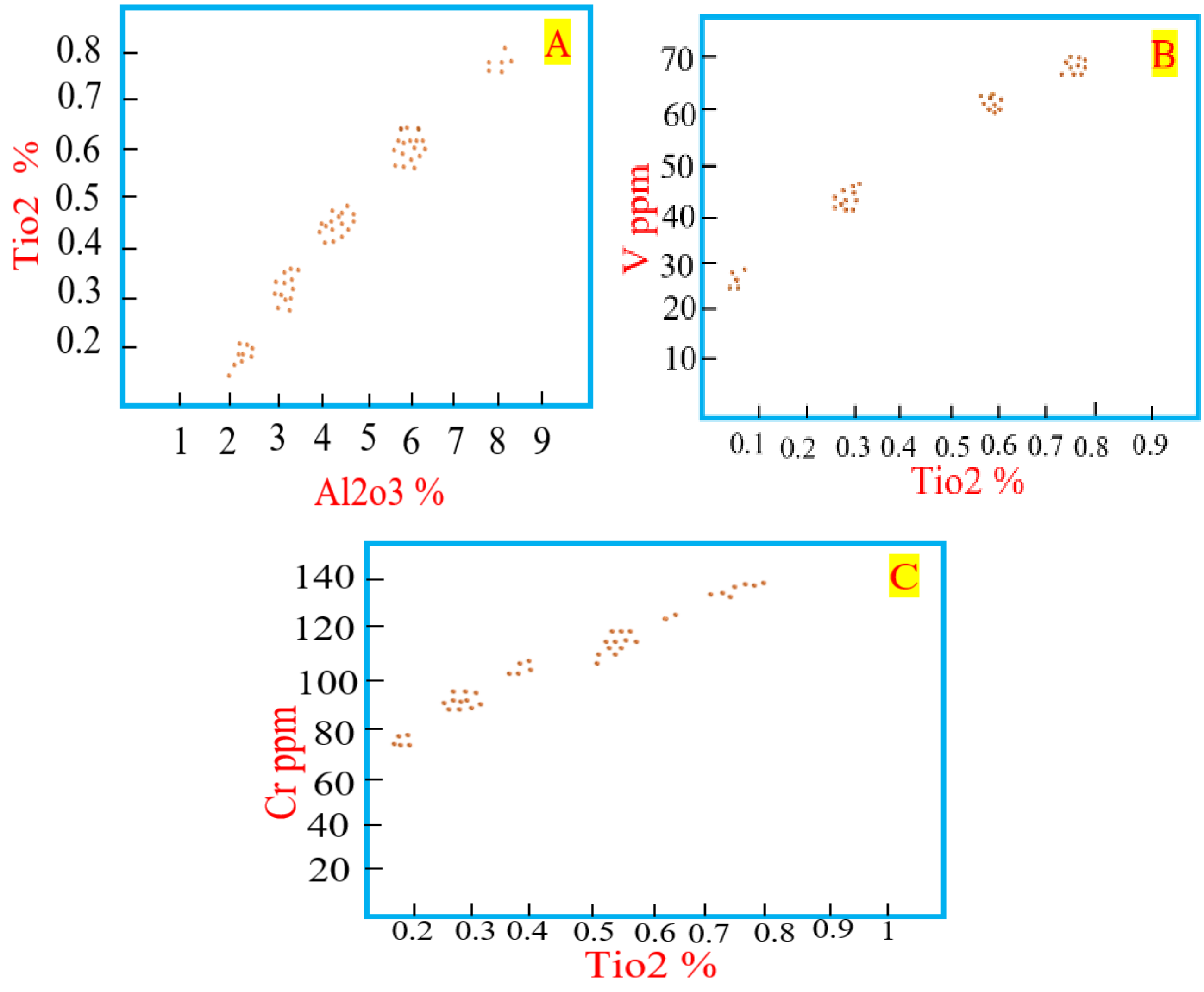


Fig. 8. Spatial Arrangement of the Two-Dimensional Plot Highlighting the Positive Correlation between Titanium Oxide, Aluminum Oxide, and Secondary Elements (V and Cr).

4.7. Geochemical Classification of Sandstones Using the Herron Index (1988)

The Herron index (1988) employs a graph plotting log (Fe2O3/K2O) against log (SiO2/K2O) to categorize sandstones. Analysis of data from the studied sections, specifically from sandstone samples extracted from the Aghajari formations and the Lehbari section, indicates that the majority of samples within the surveyed area fall within the litho-arenitic to iron-bearing sandstone range, with iron-bearing shales also represented (See Figure 9). Geochemical Classification of Sandstones Based on the Petty John et al. Index (1987). The classification of clastic sandstones utilizing the index proposed by Petty John et al. (1987) involves plotting log (Na2O/K2O) against log (SiO2/Al2O3), utilizing chemical maturity indices. The graphical representation of the primary factor analysis results is presented in Figure 10. The data reveals that a significant portion of the sandstone samples exhibit a litho-arenite composition, a finding consistent with the petrographic data.

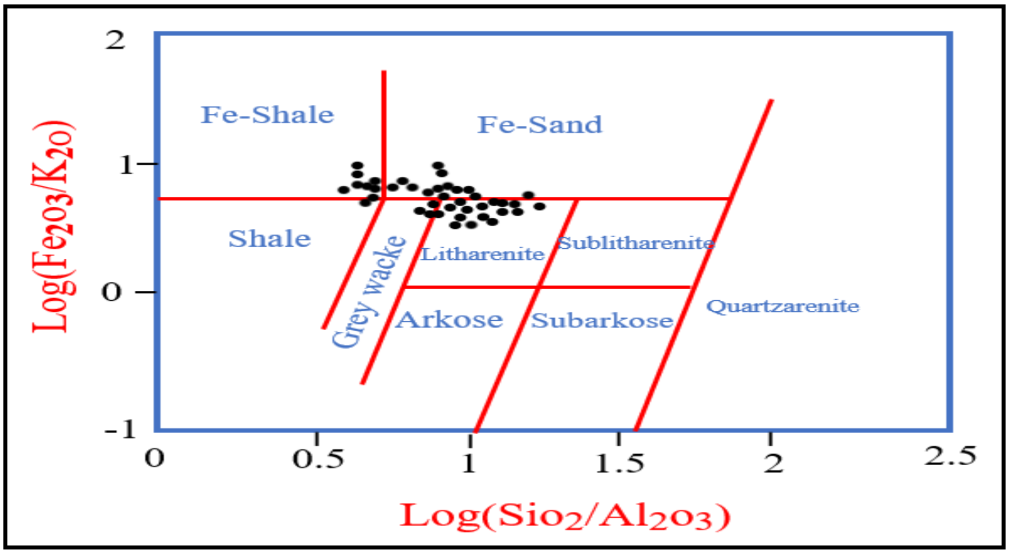


Fig. 9. Geochemical Categorization of Analyzed Samples Utilizing Herron's (1988) Diagram.

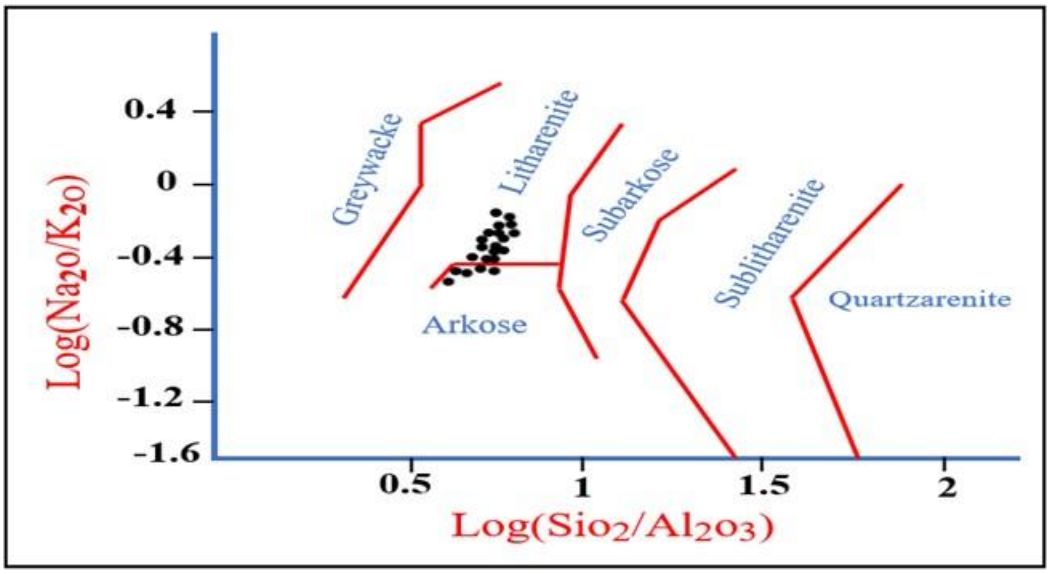
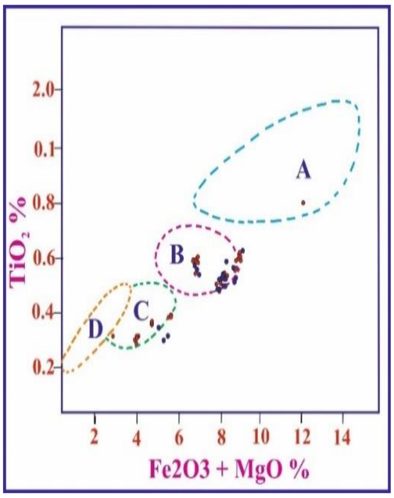


Fig. 10. Geochemical Typification of Examined Samples Illustrated on Pettijohn's (1987) Graph.

4.8. Determining the Geological Position of Sediments.

Assessment of the tectonic setting of sediments within the study area, as per Bhatia's diagram (Bhatia, 1986), reveals a prevailing inclination towards continental arc islands and active continental margins (See Figure 11). The deviation of samples from the ranges delineated by Bhatia (1986) may be attributed to the presence of Fe2O3 and MgO oxides within the network of carbonate pebbles in the analyzed sand samples (Heidari and Raheb, 2020; Pourmorad et al., 2022).



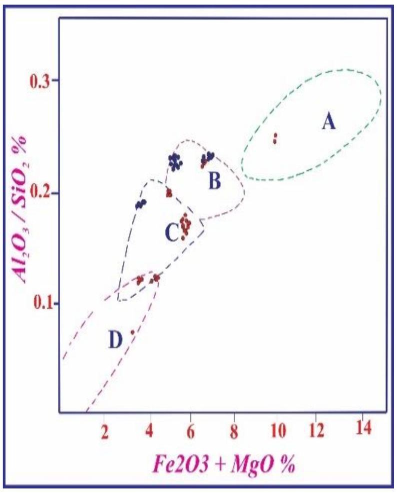


Fig. 11. Establishing Sedimentary Tectonic Setting in the Research Zone Utilizing Bhatia's (1986) Diagram.

Mineralogical investigations indicate that violet chlorite is the predominant clay mineral within the deposits under study, particularly in this region. Additionally, non-clay minerals such as calcite, quartz, feldspar, and dolomite are present in these deposits, with gypsum also observed in the study area as another non-clay mineral (Refer to Table 2). Hydrochemical analyses of underground water sources in the region reveal elevated levels of elements such as chlorine (Cl), nickel (Ni), calcium (Ca), and magnesium (Mg) surpassing permissible limits. The presence of Cl and Ni is likely attributed to oil pollution, while elevated levels of calcium and magnesium are likely linked to geological formations within the area (See Table 2).

Table 2. Mineralogical results of some studied samples in the studied area.

XRD - Analysis results	**Sample number**
Calcite, quartz, dolomite, feldspar, gypsum clay minerals	Om-10
Calcite, quartz feldspar, some dolomite and clay minerals	Om-20
Calcite, quartzfeldspar, illite, dolomite, and clay minerals	Om-30
Calcite, quartz orthosis, dolomite, feldspar, clay minerals	Om-40
Calcite, quartz, dolomite, feldspar, clay minerals and gypsum	Om-50
Calcite, quartz, dolomite, feldspar, clay minerals + gypsum	Om-60
Calcite, quartz dolomite, feldspar gypsum + clay minerals	Om-70
Calcite, quartz feldspar + dolomite	Om-80
Calcite, quartz dolomite, gypsum feldspar + clay minerals	Om-90
Calcite, quartz, dolomite, feldspar + clay minerals and gypsum	Om-100

Furthermore, tests and analyses of deep well water indicate no microbial contamination issues but highlight concerns regarding dissolved salts and ions. Specifically, sulfate, calcium, and magnesium levels exceed standard limits, with sulfate and magnesium concentrations surpassing 250 and 30 mg/liter, respectively. The presence of calcium and magnesium elements, along with water hardness, can be attributed to the compact nature of soil surface texture and its impermeability. Moreover, the detection of certain heavy elements such as chromium exceeding standard concentrations, along with elevated levels of other compounds beyond recommended thresholds, underscores water contamination in wells within the study area. Factors contributing to this contamination include improper discharge of industrial wastewater and agricultural toxins, as well as the utilization of pesticides and poisons containing heavy metals in agricultural regions. The presence of both large and small industries, alongside oil and gas sources, and the proximity of main and secondary roads with heavy traffic further exacerbate water pollution, as incomplete combustion of fuel releases heavy metals into the environment.

5. CONCLUSION.

The comprehensive study of the alluvial fans in southwestern Iran, particularly near Omidiyeh City, has yielded significant insights into the geological, geochemical, and environmental characteristics of these sedimentary formations. The research, encompassing petrographic, geochemical, and morphotectonic analyses, highlights several key findings:

- Sedimentary and Mineralogical Insights: The petrographic analysis confirms that the alluvial fan sediments are predominantly composed of rock fragments, including chert, limestone, sand, and igneous rocks, with a significant proportion of quartz and feldspar. This supports the classification of the sediments as litho-arenite. The well-rounded to semi-angular grain profiles classification of the sediments as litho-arenite. The well-rounded to semi-angular grain profiles observed in the sediments, alongside varying degrees of feldspar weathering, indicate dynamic sedimentary processes and suggest a diverse source material.

- Geochemical Characterization: The geochemical analysis reveals that calcium oxide (CaO) and silica oxide (SiO_2) are the most abundant oxides in the sediments, reflecting the influence of calcareous and siliceous processes in sediment formation. Lower concentrations of other oxides, such as sodium oxide (Na_2O) and phosphorus pentoxide (P_2O_5), suggest specific mineralogical and geochemical conditions. The presence of titanium (Ti), zirconium (Zr), and rare earth elements (REEs) like cerium (Ce) and lanthanum (La) further enriches the geochemical profile, indicating a significant presence of titanium-bearing minerals and rare earth elements.

-Environmental and Economic Implications: The study underscores the critical role of alluvial fans in groundwater recharge and mineral resource potential. The sediments' composition and the presence of valuable minerals, including titanium and zirconium, highlight the economic significance of these deposits. Additionally, the analysis of rare earth elements provides insight into the potential for rare earth mineral extraction.

- Hydrochemical and Environmental Concerns: Hydrochemical analyses of groundwater reveal elevated levels of contaminants such as chlorine (Cl), nickel (Ni), calcium (Ca), and magnesium (Mg), which exceed permissible limits. These elevated levels are attributed to industrial activities, oil pollution, and agricultural practices, with specific concerns regarding water hardness and contamination from heavy metals. The findings emphasize the need for improved water management and pollution control measures in the region.

- Geological and Tectonic Context: The tectonic setting of the sediments suggests a predominance of continental arc islands and active continental margins. The presence of various minerals, including calcite and gypsum, along with deviations in oxide concentrations, provides valuable context for understanding the geological history and tectonic influences on sediment deposition.Overall, this research offers a comprehensive understanding of the alluvial fan system in southwestern Iran. The detailed geochemical and mineralogical data enhance our knowledge of sedimentary processes, environmental impacts, and resource potential, providing a valuable reference for future studies and resource management efforts in similar geological settings.

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