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# From sediment to structure: Technological and industrial prospects of natural gypsum in sustainable construction

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## Abstract

Natural gypsum, which is composed of calcium sulfate dihydrate, is attracting renewed interest due to its environmental compatibility and its numerous applications in construction and related industries. This study investigates the geological, technological, and industrial potential of natural gypsum, emphasizing its role in sustainable construction. A comprehensive literature review was conducted to analyze the formation conditions of gypsum-bearing strata across key geological epochs, particularly the Permian, Triassic, and Miocene, highlighting patterns in their spatial and temporal distribution both globally and within Kazakhstan. These findings were integrated with a case analysis of the Shert gypsum-anhydrite deposit in southern Kazakhstan. Methodologically, the study is based on archival geological maps, borehole data, and technical-economic reports to assess the lithological structure, mineral composition, and resource viability. The results confirm the presence of high-purity gypsum (over 84% $CaSO_4 \cdot 2H_2O$), low groundwater inflow, and consistent economic profitability. This makes the deposit suitable for producing construction materials such as gypsum boards, plaster, and sulfate-resistant cement. The study concludes that the link between paleogeographic conditions and mineral quality has practical implications for material selection and sustainable resource development. These findings could provide a framework for evaluating similar deposits and optimizing the use of natural gypsum in environmentally conscious engineering practices.

**Keywords:** 3D printing, Composite materials, Geology of Kazakhstan, Gypsum anhydrite, Industrial feasibility, Mineral resources, Natural gypsum, Shert deposit, Sustainable construction.

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## 1. Introduction

Natural gypsum, a soft mineral consisting of calcium sulfate dihydrate ($CaSO_4 \cdot 2H_2O$), is widely used in various industries due to its unique chemical and physical properties. Its abundance and versatility make it an indispensable material for the construction, medical, agricultural, and chemical industries.

Gypsum's most common use is in the production of building materials, particularly gypsum boards and plaster mixtures. Gypsum is used for interior wall and ceiling finishes thanks to its fire resistance, acoustic properties, ease of installation, and environmental safety [1]. Additionally, gypsum plays a vital role in the cement industry by regulating the setting rate of cement mortar and ensuring optimal curing time [2].

Fire-resistant gypsum products are of particular importance, and the development of these products has become a priority in construction composite technology in recent decades. Modern gypsum refractories contain various additives, such as organic acids, alkaline phosphates, and protein compounds, which act as retardants. These additives affect not only the rate at which gypsum sets but also the strength, plasticity, and crystal structure morphology of the finished product [3]. As global production of gypsum materials increases, using such additives enables the material to be customized to meet specific construction requirements.

Despite the obvious advantages, the gypsum industry in Kazakhstan faces a number of challenges. The main barriers are the high transportation costs and the uneven quality of natural gypsum deposits. Furthermore, the issue of the rational processing of technogenic waste containing gypsum compounds remains unresolved. Gypsum waste generated in the ceramic, chemical, and construction industries is often utilized inefficiently, despite its proven potential for reuse in the production of building materials [4].

Against the background of growing volumes of construction and industrial waste, the need for an environmentally sustainable approach to the use of gypsum becomes especially urgent. For instance, approximately 900 million tonnes of construction and demolition waste are produced in European Union countries each year, over 15 million tonnes of which contain gypsum [5]. Recycling these wastes and using synthetic analogues of gypsum, such as phosphogypsum and flue gas desulfurization gypsum (FGD gypsum), can significantly reduce the burden on natural resources and the environment [6].

In the face of increasing environmental and resource challenges, there is therefore a growing need for a comprehensive study of natural gypsum as a strategically important material for the sustainable development of the construction industry.

This study aims to identify the potential applications of natural gypsum as a technological product by considering its geological features, physical and chemical properties, and formation conditions. Particular focus is given to gypsum deposits in Kazakhstan with industrial potential, considering modern requirements for the environmental friendliness and manufacturability of construction materials.

The scientific novelty of the study lies in its systematic approach to investigating the relationship between the facies-paleogeographic conditions of gypsum stratum formation and their technological properties. This analysis enables us to justify the selection of raw materials for specific use in construction and other industries and to evaluate the competitiveness of Kazakhstani gypsum in the global market.

## 2. Literature Review

### *2.1. Scientific Problem, Hypothesis and Research Objectives*

#### *2.1.1. Scientific Problem*

Despite gypsum's widespread use in construction, medicine, and other industries, significant gaps remain in our understanding of its historical and geological evolution, the regularities of its spatial and temporal distribution, and its interrelation with tectonic, climatic, and paleogeographic factors. While modern publications mainly focus on the technological aspects of gypsum use, fundamental studies aimed at a comprehensive analysis of the formation and transformation conditions of gypsiferous deposits remain fragmentary and poorly systematized. This makes it difficult to accurately interpret the origin of gypsum, predict deposits, and justify its use in a sustainable way in the construction industry and other areas.

#### *2.1.2. Research Hypothesis*

A comprehensive analysis of the geological, structural, climatic, and paleogeographic factors that influence the formation of gypsum-bearing strata in different geological epochs will enable us to identify the regularities in their spatial distribution. This will allow us to create a classification of gypsum-forming settings that can be used in both regional stratigraphy and in tasks related to the extraction and use of gypsum.

*2.1.3. Research Questions*

1. What geological and climatic conditions contributed to the formation of thick gypsiferous strata during different geological periods?
2. What types of gypsum-forming environments can be identified through stratigraphic and spatial analysis?
3. How did the paleogeography of areas with gypsiferous deposits change over time?
4. How can the obtained data be used to predict gypsum deposits and justify gypsum applications?

*2.1.4. Research Objective*

The objective of this research is to develop a geological and paleogeographic model of gypsum-bearing stratum formation. This will be achieved by analyzing their spatial and temporal distribution, as well as the geodynamic and climatic conditions. The aim is to clarify the regularities of gypsum formation and identify potential applications.

*2.1.5. Research Objectives*

- To review the current scientific data on gypsum lithogenesis and the classification of gypsiferous strata, as well as the conditions under which they formed.
- To identify the main tectonic, climatic, and hydrogeochemical factors that affect gypsum formation.
- To systematize gypsum-forming conditions by geological epoch and region.
- To construct a summary paleogeographic map (or table) showing the distribution of gypsiferous formations.
- To analyze the practical applications of gypsum in construction and medicine based on its mineralogical properties.
- To demonstrate the practical significance of the results for predicting deposits and for the rational application of gypsum.

*2.2. Geology And Formation of Gypsum Deposits*

*2.2.1. Facies Conditions of Gypsum Formation*

Gypsum is a valuable natural material with a wide range of applications, and its geological formation is closely related to specific facies and palaeogeographic conditions. In order to better understand the technological potential of gypsum, particularly in relation to deposits in Kazakhstan, it is necessary to consider the theoretical basis of its genesis and to summarize the existing scientific data on the formation of gypsum rocks, their types, properties, and conditions of accumulation. This review focuses on the conceptual framework and geological conditions underlying the formation of gypsum-bearing complexes, especially under the natural conditions of Kazakhstan.

Every field of the natural sciences has its own specific terms or expressions that reflect the influence of physical and chemical processes on the subject matter. In earth sciences, such a term is 'facies,' and since its introduction to the literature by Steno [7] it has undergone many changes. Gressly [8] published a work in which he distinguished freshwater, brackish-water, and marine sediments based on changes in lithological composition in the Jurassic strata of eastern France. He considered changes in petrographic composition, geological features, and paleontological features to be criteria for distinguishing facies. Around the same time, Prevost distinguished between pelagic, subpelagic, and littoral facies zones, as well as coral and sponge facies. Thus, the concept of 'facies' encompasses sediments and the primary organic components found within them. E. Suess applied the concept of facies in the same way [9].

The facies conditions of gypsum rock formation in Kazakhstan are closely related to the region's arid continental climate and the presence of large sedimentary basins, which contribute to the accumulation of evaporite (chemogenic) deposits. The main factors and conditions are: an evaporitic (chemogenic) environment, in which gypsum forms as a result of the evaporation of mineral-rich waters in shallow lagoons and closed basins; stratigraphic features, in which gypsum deposits are most often found in cover rocks (eluvium) over salt beds of Permian age or younger; and weathering, accompanied by salt leaching and the redeposition of sulfate minerals [10].

Hydrogeological conditions play a key role in this process: the movement of groundwater saturated with carbonates and sulfates not only leads to the formation of gypsum but also to the development of karst processes and suffusion. This is especially pronounced in the regions of Western Kazakhstan. Gypsum massifs are often geomorphologically elevated above the surrounding landscape, as can be seen in the Lake Inder area, where gypsum is exposed up to 40 metres above lake level. In such zones, the rocks are clearly fractured and covered by loose sandy loam layers [11].

From a paleogeographical perspective, the most significant gypsum-bearing formations in Kazakhstan emerged during the stable aridification period of the Permian era (Kungurian stage) and are confined to lagoonal and solonchak basins, which are typical of the southern Urals. Here, calcium- and sulfate-bearing brines interacted with clay sediments, undergoing complex diagenetic and catagenetic processes that included the formation of associated minerals such as celestite (strontium sulfate) and magnesite [12].

*2.2.2. Gypsum-rich geological epochs (globally and in Kazakhstan)*

There are epochs around the world that are rich in gypsum formations.

Such formations typically occur in sedimentary layers from the evaporation of ancient water bodies. Some geological eras are particularly notable for their extensive gypsum deposits.

Major eras containing gypsum worldwide:
The Permian period (299–252 million years ago):

Extensive deposits of gypsum and other evaporites from this period are well known in many parts of the world, especially due to widespread arid conditions and large inland seas that dried up over time [13].

The Triassic period (252–201 million years ago):

Large gypsum formations were found, especially in Europe (e.g., the French Alps), due to arid conditions and the breakup of the supercontinent Pangaea.

The Messinian period (late Miocene, about 7.2–5.3 million years ago):

The Messinian Salinity Crisis in the Mediterranean Sea led to the formation of massive gypsum beds, representing some of the world's largest evaporite deposits [13, 14].

Gypsum minerals have been forming since the Archean eon, but the epochs described above are notable for their large-scale deposits due to distinctive global climatic and tectonic conditions [13, 15].

Gypsum deposits in Kazakhstan.

The country's geology is characterized by extensive Paleozoic sediments and sedimentary basins containing evaporites, including gypsum.

Key periods for gypsum mining in Kazakhstan:

*2.2.2.1. The Permian and Triassic Eras*

These eras were important for the formation of many mineral deposits, including evaporites such as gypsum. Basin conditions exposed to evaporation during these periods favored the significant accumulation of gypsum [13].

*2.2.2.2. Jurassic to Cretaceous*

Continued sedimentation and activation processes also contributed to the deposition of gypsum in certain basins.

Kazakhstan contains large deposits of sedimentary rocks from the Paleozoic and Mesozoic eras, with gypsum often found in layers formed by evaporation in continental and marine basins. These formations often coincide with tectonic activity, which affects the size and preservation of sediments [16]. The diversity of gypsum forms in nature can be seen in macroscopic crystals and aggregates, as well as in bedded veins embedded in sedimentary rocks (see Figures 1 and 2).


**Figure 1.**
A variety of natural gypsum formations.
**Source:** Geology In [15].

**Figure 2.**
Layered veins of gypsum embedded in sedimentary rocks. Photo: Open source.

Gypsum accumulations in Kazakhstan are commonly found alongside structural features such as synclines, anticlinal axes, and fault lines, particularly in areas where water runoff and evaporation are prominent, especially in arid and semi-arid regions. To summarize the geological data on the distribution of gypsum deposits during different periods of geological history, the following table presents key epochs and regions with the highest concentrations of gypsum, both globally and within Kazakhstan.

**Table 1.**
Summary table: Epochs rich in gypsum

| Region | Epoch/Period | Notes |
|---|---|---|
| Worldwide | Permian | Extensive global evaporites; large deposits in Europe, Asia, N. America |
| Worldwide | Triassic | Thick, widespread European formations (e.g., Alps) |
| Worldwide | Messinian (Miocene) | Mediterranean "salt giant" evaporites, massive gypsum beds |
| Kazakhstan | Permian–Triassic | Major gypsum deposition across sedimentary basins |
| Kazakhstan | Jurassic–Cretaceous | Subsequent sediment reactivation and additional deposition |

The Permian and Triassic eras were particularly significant periods for gypsum deposits, both globally and in Kazakhstan. There was also notable additional accumulation during the Messinian period (Miocene) on a global scale. The Paleozoic and Mesozoic eras were also significant in Kazakhstan due to the region's geology and climate at that time.

*2.3. Application of Gypsum in Various Industries*

*2.3.1. Building Materials and Standards (Drywall, Plasters, etc.)*

Gypsum is a versatile mineral used in modern construction thanks to its fire-resistant, sound-insulating, and moisture-regulating properties, as well as its resistance to mold. It is used in building materials such as drywall, plaster, and fiberboard. Drywall is used to finish interior walls and ceilings; plaster provides a smooth finish; and walls, ceilings, floors, and partitions are clad with fiberboard. Cement additives also regulate setting time. Gypsum is also used for decorative mouldings, architectural elements, precast panels, and as an underlay in flooring, partition systems, and sculptures [17, 18].

Gypsum's wide application in the construction industry as a functional component of various materials is due to its physical and chemical properties. It provides fire resistance, sound insulation, moisture resistance, thermal insulation, and a decorative finish, playing a key role in the creation of modern building systems. These properties are particularly important in the design of interior partitions, room finishes, and prefabricated structures. Table 2 summarizes the main performance characteristics of gypsum and how they are implemented in building materials.

**Table 2.**
Performance and Functional Benefits.

| Property | Building Material Examples | Benefit |
|---|---|---|
| Fire Resistance | Drywall, plaster, fibreboard | Inherent non-combustibility slows fire spread |
| Sound Absorption | Drywall, fibreboard, ceiling tiles | Reduces noise transmission |
| Moisture Resistance | Green board, treated drywall | Longevity in wet environments |
| Thermal Insulation | All gypsum boards/plasters | Improves room comfort and energy efficiency |
| Smooth Finishing | Plasters, drywall | Ideal for decoration, painting |
| Fast Setting/Hardening | Plaster, ready-mix products | Speeds up construction, reduces labor costs |
| Sustainability | All gypsum products | Recyclable, low-carbon, supports green building |

**Source**: Grand View Research [18] and Celotech Chemical [19].

Gypsum-based construction materials are subject to stringent international and national standards to ensure quality, safety, and durability. These standards include ASTM C1396/C1396M, ASTM C471M, and ASTM C1264. Compliance with these standards is often legally required, especially for sulfur content to avoid issues like metal corrosion in homes. Similar standards are enforced by EN, ISO, and BSI for gypsum boards and plasters. The global gypsum plaster market is experiencing strong growth due to prefabricated construction, renovations, and sustainability initiatives. Synthetic gypsum is gaining ground as a sustainable alternative [20, 21].

*2.3.2. Medical Use (Immobilization, Dentistry, etc.)*

Plaster has been used for centuries as a stiffening agent for fractures and other musculoskeletal conditions. Despite modern metallurgy and internal stabilization, plaster casts and splints remain crucial for external stabilization. The history of immobilization reveals a progressive development, culminating in Mathijsen [22] plaster bandage in 1851. The introduction of calcium sulfate in 1798, crinoline rolls in 1927, and synthetic casting tapes in the 1970s highlight the importance of proper casting technique. Plaster remains a vital treatment method for acute and chronic orthopaedic conditions [23].

Gypsum, a mineral composed of calcium sulfate dihydrate, is crucial in dental laboratories for the manufacture of prosthetics. It is used to create anatomical studios and working models, and various types of plaster are used, such as alabaster, blue, hard, and yellow. Alabaster gypsum is used to make anatomical prints, articulator models, solid gypsum for precision models, and super-hard gypsum for working models and mobile dentures [24].

*2.3.3. New Technologies and Environmental Solutions*

3D-printed building construction technology is growing in countries like France, China, and Russia, offering architectural diversity, speed, and automation. However, there are challenges to this technology, such as choosing the right mixture with gypsum and gypsum-cement binders, and designing buildings with rational structural solutions for roofs and floors. Field tests were conducted on large-sized wall blocks filled with light porous expanded clay, expanded clay concrete, or heat-insulating foam gypsum. Frame-monolithic beam structures made of metal, thin-walled steel galvanized profiles were used for optimal floor design. The rapid introduction of 3D printing technology in construction has led to the construction of residential areas and individual houses. The technology has also allowed for the exclusion of manual labor, the installation of electrical cables, water pipes, and pipes for heating and ventilation, and waste-free construction. Figure 3 shows the construction of a settlement using 3D printing technology in the village of Aisha in the Republic of Tatarstan [25].

**Figure 3.**
Construction of a settlement using 3D printing technology in the village of Aisha, Republic of Tatarstan, Kuznetsov et al. [25].

These technological trends demonstrate gypsum's expanding role in sustainable and automated construction, pointing to its growing importance in future building practices.

Composite materials are classified according to structure, geometry, and performance requirements, with various gypsum-based matrices provided as examples. Various hardening mechanisms of gypsum binders make it possible to combine reinforcing elements into a single conglomerate with a compressive strength of more than 100 MPa. The production process is environmentally friendly and increases the strength of the matrix. Both pure gypsum and gypsum–cement composites have great prospects for use in construction and 3D printing technologies [26].

*2.4. Conclusions from the Literature Review*

Gypsum is a multidisciplinary material that forms under specific geological conditions, particularly in arid and marine basins during the Permian and Triassic periods. It is prevalent in formations in Kazakhstan, including Zhanatas, Shybyndyk, and Mangyshlak, where favourable lithological, stratigraphic, and climatic conditions converge.

Gypsum is widely used in construction for drywall, plaster, decorative panels, and acoustic and thermal insulation elements, providing fire resistance, sound and moisture insulation, fast installation, and environmental friendliness. The table below outlines the functional and operational advantages that ensure its widespread use in residential and industrial construction.

In medical practice, gypsum remains indispensable for immobilization due to its ability to harden quickly, mold tightly to the body, and retain its shape. Research indicates an emerging trend toward the development of composites that combine gypsum with polymers, glass fibers, and other additives.

Current research is increasingly focused on developing gypsum composites that are durable, environmentally friendly, and suitable for 3D printing. High strength (over 100 MPa), processability, low energy consumption during production, and recyclability make gypsum an important element in green architecture and sustainable construction.

This review highlights both the diverse applications of gypsum and the geological factors influencing its formation. However, the link between its genesis and industrial significance in Kazakhstan remains understudied and merits further detailed research.

## 3. Materials and Methods

This study is based on archival geological, cartographic, and analytical materials relating to the Shert gypsum-anhydrite deposit in the Turkestan region of Kazakhstan. The aim is to evaluate the deposit's industrial and geological characteristics by integrating spatial data, lithological descriptions, and technical and economic evaluations. The methodology incorporates the interpretation of borehole data, structural mapping, and reserve calculations to ensure continuity with the lithogenetic and application-related insights presented in the literature review.

*3.1. Geological Setting and Deposit Characteristics*

The Shert deposit is located 22 km west of the town of Kentau and 6 km from the Atabai railway station. Geologically, it is confined to the Bashkirian stage of the Middle Carboniferous period, and it is represented by a 3.4 km long and 1.8 km wide lens-shaped body of gypsum and anhydrite. The formation's overall thickness reaches 1000 m, while the industrially viable gypsum-bearing layer attains a maximum thickness of 72 m.

Three main lithological varieties are distinguished: pure gypsum, gypsum–anhydrite, and pure anhydrite. Each variety has distinct mineralogical features.

*3.2. Methodology of Data Collection*

Topographic mapping was performed at scales ranging from 1:25,000 to 1:2,000. Surveying was based on a triangulation grid established using metal benchmarks and a vertical reference system aligned with the elevation of the Baltic Sea. Borehole coordinates were defined using polar referencing based on a detailed survey grid. This study used a total of 18 boreholes to provide data on X, Y, and H coordinates across the central portion of the lease area Figure 4.

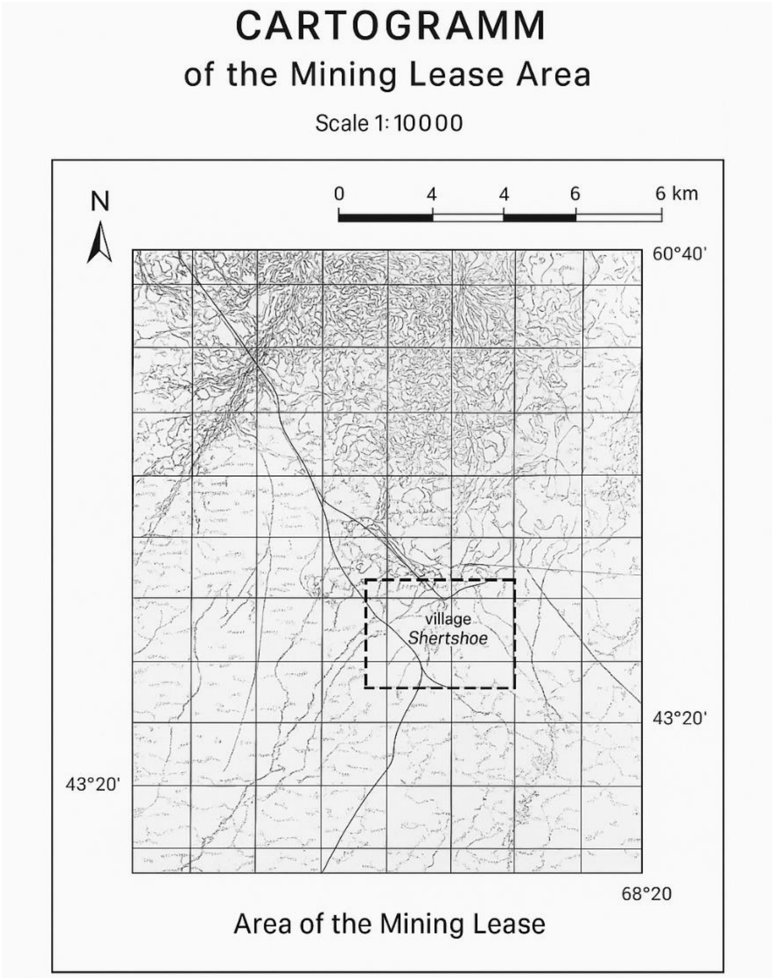


**Figure 4.**
Topographic base map with borehole coordinates across the Shert gypsum deposit (Compiled from archival survey data).

*3.3. Mineralogical and Physical-Chemical Characterisation*

Mineralogical and chemical data were extracted from the reserve validation protocol (No. 8632, 1980). On average, the gypsum content is 84.9% ($CaSO_4 \cdot 2H_2O$), whereas the anhydrite content can reach 93.4% ($CaSO_4$). Associated minerals include calcite, quartz, barite, and pyrite. Laboratory testing confirmed that anhydrite is suitable for producing high-strength cement when heated to between 600 and 800 °C.

*3.4. Technical and Economic Indicators*

The deposit is classified as hydrogeologically dry, with minimal groundwater inflow (0.3–0.5 L/s), which favors open-pit mining operations. The reserve estimates are presented below.

**Table 3.**
Reserve classification for the Shert gypsum deposit

| Resource Type | Reserve Category (million tonnes) |
|---|---|
| Gypsum | $A+B+C_1+C_2$: 39.971 |
| Anhydrite | $A+B+C_1+C_2$: 57.904 |
| Total Balance Reserves | 97.875 |
| $C_2$ Category | 3.554 |

In addition to the geological reserves, a set of technical and economic indicators was compiled based on the feasibility estimates. These include stripping volumes, production rates, cost estimates, and calculations of profitability.

**Table 4.**
Technical and Economic Indicators for the Shert Gypsum Deposit.

| Indicator | Unit | 2003 | 2007 | 2010 | 2013 | 2015 |
|---|---|---|---|---|---|---|
| Overburden volume | m³ | 45.000 | 55.000 | 60.000 | 60.000 | 60.000 |
| Gypsum-anhydrite extraction volume | m³ | 30.000 | 70.000 | 90.000 | 100.000 | 100.000 |
| Total gypsum extraction | tonnes | 78.000 | 482.000 | 208.000 | 260.000 | 260.000 |
| Total expenses on mining | KZT '000 | 20.322 | 37.119 | 41.471 | 49.569 | 50.175 |
| Unit cost per 1 tonne of gypsum | KZT | 261 | 204 | 199 | 191 | 193 |
| Total expenses on processing | KZT '000 | 199.476 | 444.890 | 505.358 | 632.054 | 633.659 |
| Gypsum board production output | tonnes | 25.000 | 45.000 | 45.000 | 45.000 | 45.000 |
| Gypsum cement production | tonnes | 7.979 | 9.886 | 11.252 | 14.068 | 14.081 |
| Marketed product value | KZT '000 | 230.000 | 513.000 | 580.500 | 729.000 | 729.000 |
| Net profit | KZT '000 | 30.524 | 68.110 | 74.142 | 95.946 | 95.341 |
| Profit per tonne | KZT | 1.153.0 | 1.153.1 | 1.146.4 | 1.150.5 | 1.153.0 |
| Profitability (%) | % | 14 | 15 | 16 | 15 | 15 |
| Realized gypsum-anhydrite (for sale) | tonnes | 84.800 | 219.200 | 260.800 | — | — |

The data in Table 4 show the technical and economic aspects of gypsum extraction and processing at the Shert deposit over 12 years. Key metrics include overburden removal, extraction volumes, total production, costs, and profitability. Notably, the unit cost of gypsum production decreased gradually between 2003 and 2015, while profit per tonne remained consistently high. These figures highlight the economic viability of continued development of the deposit for the production of gypsum board and gypsum cement. The combination of increasing production output and stable profitability emphasizes the strategic importance of this resource for the regional industry and its export potential.

*3.5. Summary of the Methodological Framework*

The methods employed in this study enabled a thorough evaluation of the Shert gypsum deposit from geological and industrial viewpoints. Integrating spatial borehole data, mineralogical composition, and economic indicators enabled a detailed characterization of the deposit's potential. Particular focus was placed on correlating lithological features with the reserve structure and the technological suitability of the raw material for the production of gypsum boards, cement, and composites.

Combining archival geological reports, field survey data, and laboratory analyses provides a solid basis for understanding the genesis, structure, and economic viability of gypsum reserves in Kazakhstan. These findings also establish a methodological link between the facies-paleogeographic conditions discussed in the literature and real-world production indicators.

This methodological framework will support the subsequent interpretation of the results, in which the geological characteristics and technological assessments will be analyzed together to evaluate the industrial and environmental prospects of gypsum mining in the region.

## 4. Results and Discussion

This section presents the main findings of the geological, mineralogical, and economic analyses of the Shert gypsum deposit, discussing their significance in relation to the technological use of gypsum.

*4.1. Spatial and Lithological Structure of the Deposit*

Analysis of borehole data confirmed the presence of a thick, lens-shaped gypsum–anhydrite body with a maximum thickness of 72 meters, and the mineralogical composition is consistent across most boreholes. This indicates homogeneous depositional conditions during the Bashkirian stage. The lateral continuity of the gypsum layer and its uniform quality make it favorable for sustained industrial exploitation.

*4.2. Quality and Composition of Gypsum*

The average content of $CaSO_4 \cdot 2H_2O$ in gypsum exceeds 84%, while pure anhydrite contains up to 93.4% $CaSO_4$. These parameters align with industry standards for construction and high-strength applications. Minor impurities such as calcite, quartz, and barite do not significantly affect usability and may even enhance binding properties in composite formulations.

*4.3. Technological Implications*

Laboratory roasting experiments showed that the mineral composition of Shert gypsum is ideal for producing gypsum products for construction, including boards and plasters. Anhydrite can also be used for producing sulfate-resistant cement. These findings are consistent with earlier reports (e.g., Protocol No. 8632) and demonstrate the deposit's potential for a variety of technological applications, including the development of heat-resistant or fast-setting composites.

*4.4. Economic Feasibility*

The economic indicators confirm the profitability of extracting and processing gypsum at the deposit. With production costs remaining low in recent years and profitability margins of up to 16%, the Shert deposit represents a stable source of raw material with favorable market outlooks. The steady increase in the value of the marketed product and profitability highlights the long-term sustainability of industrial development based on this resource.

*4.5. Strategic Importance for Kazakhstan*

Given its size, accessibility, and mineral quality, the Shert deposit has significant industrial potential for southern Kazakhstan. It can not only supply domestic construction needs but also serve as a source of export-grade gypsum products. This is particularly relevant in the context of growing interest in environmentally friendly, recyclable materials. Furthermore, the deposit has the potential to encourage innovation in 3D printing and composite development, making it pertinent to emerging green construction technologies.

## 5. Conclusion

This study provides an integrated analysis of gypsum as a geological and technological resource. It combines a literature-based review of its origin, formation environments, and industrial applications with a detailed case study of the Shert gypsum-anhydrite deposit in Kazakhstan. The research confirms that gypsum, particularly that from arid and evaporitic Permian and Triassic basins, has the mineralogical and structural qualities required for modern construction materials such as gypsum boards, plasters, and high-strength cement. The Shert deposit is a prime example of this, providing a high-purity raw material and favorable economic indicators such as low production costs and stable profitability margins.

Beyond the Shert deposit, this work highlights the broader industrial relevance of gypsum in sustainable building technologies, including 3D printing and composite materials. The mineral's inherent recyclability and compatibility with eco-friendly additives place it at the forefront of green construction initiatives. The study also demonstrates the value of connecting paleogeographic and lithogenetic insights with technological assessments to better predict resource potential and guide rational exploitation strategies.

Overall, the abundance of gypsum in Kazakhstan, coupled with its unique properties, positions it as a strategic material for both domestic use and international markets. Future research could build on this foundation by exploring synthetic analogues, optimizing composite formulations, and assessing the environmental impact of gypsum throughout its life cycle.

## References


[1] S. Ashcroft, "Focus on: Gypsum, a building block for world construction," Mining Digital, 2024.

[2] M. c. w. g. B. applications, "Modern construction with gypsum: Benefits & applications," Mada Gypsum, 2024. https://www.madagypsum.com/modern-construction-with-gypsum-benefits-applications

[3] X. Ding, W. Huang, Y. Li, Z. Hu, and Z. Shan, "Study on retarding feature and retardation mechanism of various retarding materials on gypsum as a construction material: A review," *Journal of Building Engineering,* vol. 72, p. 106569, 2023. https://doi.org/10.1016/j.jobe.2023.106569

[4] M. Mirzajanov, B. Otakulov, S. Kuziboev, B. Mirzaev, A. Khamidov, and Z. Abdulkhaev, "Gypsum binders based on ceramic industry waste," in *E3S Web of Conferences*, 2023: EDP Sciences.

[5] S. S. Silgado, L. C. Valdiviezo, S. G. Domingo, and X. Roca, "Multi-criteria decision analysis to assess the environmental and economic performance of using recycled gypsum cement and recycled aggregate to produce concrete: The case of Catalonia (Spain)," *Resources, Conservation and Recycling,* vol. 133, pp. 120–131, 2018.

[6] D. B. Watts and W. A. Dick, "Sustainable uses of FGD gypsum in agricultural systems: Introduction," *Journal of Environmental Quality,* vol. 43, no. 1, pp. 246–252, 2014.

[7] N. Steno, *On the solid within a solid naturally contained dissertation prologue*. Florence: : Ex Typographia sub Signo Stellae, 1669.

[8] A. Gressly, "Geological observations on the Solothurn Jura," *Nouveaux Mémoires de la Société Helvétique des Sciences Naturelles, Neuchâtel,* vol. 2, p. 349, 1838.

[9] W. G. Ernst, *Geochemical facies analysis*. New York: Elsevier Publishing Company, 1970.

[10] Z. K. Tukhfatov, M. K. Jexenov, Y. K. Bektay, G. S. Turysbekova, and B. N. Shiderin, "Exploration studies for raw chemical mineral resources in the caspian basin salt domes," *Geology and Subsoil Use,* vol. 1, p. 474, 2025. https://doi.org/10.32014/2025.2518-170X.474

[11] K. Akhmedenov, D. Iskaliev, and V. Petrishev, "Karst and pseudokarst of the West Kazakhstan republic of Kazakhstan," *International Journal of Geosciences,* vol. 5, no. 2, pp. 131–136, 2014. https://doi.org/10.4236/ijg.2014.52014

[12] S. V. Michurin, R. F. Abdrakhmanov, V. N. Durnaeva, and V. F. Yuldashbaeva, "Geochemical and mineralogical features of gypsum of the kungurian stage in the southern cis-urals," *Russian Geology and Geophysics,* vol. 66, no. 3, pp. 316–330, 2025.

[13] J. Jehlička, A. Oren, P. Vítek, and J. Wierzchos, "Microbial colonization of gypsum: From the fossil record to the present day," *Frontiers in Microbiology*, Review vol. Volume 15 - 2024, 2024. https://doi.org/10.3389/fmicb.2024.1397437

[14] F. Dela Pierre *et al.*, *Gypsum as an archive of biosignatures: What can we learn from the late miocene mediterranean salt giant*. Vienna, Austria: In EGU General Assembly.

[15] Geology In, "Gypsum: Properties, uses, formation, types," 2024. https://www.geologyin.com/2024/03/gypsum-properties-uses-formation-types.html

[16] E. De Pelsmaeker, S. Glorie, M. M. Buslov, V. V. Korobkhin, and J. De Grave, *Palaeozoic emplacement and Meso-Cenozoic reactivation of the southern Kazakhstan granitoid basement. Geophysical research abstracts, 16, EGU2014-6104*. Vienna, Austria: In EGU General Assembly, 2014.

[17] Food and Agriculture Organization of the United Nations, *Management of gypsiferous soils (FAO Soils Bulletin No. 62)*. Rome, Italy: FAO, 1990.

[18] Grand View Research, "Gypsum plaster market size, share & trends analysis report by plaster system (manually-applied, machine-applied, finishes), by raw material (natural, synthetic), by end-use (residential, commercial, industrial), by region, and segment forecasts, 2025–2030 (Report ID: GVR-4-68040-533-3)," San Francisco, CA: Grand View Research, 2024. https://www.grandviewresearch.com/industry-analysis/gypsum-plaster-market

[19] Celotech Chemical, "What are the uses of gypsum," Tokyo, Japan, 2025. https://www.celotech.com/news/what-are-the-uses-of-gypsum/

[20] Fortune Business Insights, *Gypsum plaster market size, share, and industry analysis by raw material (natural and synthetic), by end use (residential and non-residential), and regional forecast till 2032 (Report ID: FBI112195)*. New York, NY, USA, 2025. https://www.fortunebusinessinsights.com/gypsum-plaster-market-112195

[21] Y. Zhang, "4 - Gypsum decorative materials," in Building Decorative Materials, Y. Li and S. Ren Eds. Cambridge, UK: Woodhead Publishing, 2011, pp. 54-74. https://doi.org/10.1533/9780857092588.54

[22] A. Mathijsen, *Development of the plaster-of-Paris impregnated bandage for immobilizing fractured limbs. First application at the military* Haarlem: Findings Published in Repertorium, 1851.

[23] M. DeMaio, K. McHale, M. Lenhart, J. Garland, C. McIlvaine, and M. Rhode, "Plaster: Our orthopaedic heritage: AAOS exhibit selection," *JBJS*, vol. 94, no. 20, p. e152, 2012. https://doi.org/10.2106/JBJS.L.00183

[24] H. Arslanov, C. Dimova, J. Vladikova, and P. Apostoloski, *Use of gypsum into working everyday in dental technician*. Sofia, Bulgaria, 2015.

[25] D. V. Kuznetsov *et al.*, "Dry mixes on gypsum and mixed bases in the construction of low-rise residential buildings using 3D printing technology," *Construction Materials and Products*, vol. 6, no. 6, p. 5, 2023. https://doi.org/10.58224/2618-7183-2023-6-6-5

[26] I. Domanskaya, V. Petropavlovskaya, T. Novichenkova, K. Petropavlovskii, and R. Fediuk, "Potential of gypsum-based matrices for sustainable composite materials: A comprehensive review," *JOM*, vol. 77, no. 4, pp. 2367–2382, 2025.