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Second Projet de Renforcement Institutionnel du Secteur Minier de la République Islamique de Mauritanie (PRISM-II)

Reported Industrial Minerals Occurrences and Permissive Areas for Other Occurrences in the Islamic Republic of Mauritania:

Phase V, Deliverable 89

By William H. Langer

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This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards or for stratigraphic nomenclature.

The report is being released in both English and French. In both versions, we use the French-language names for formal stratigraphic units.

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Reported Industrial Minerals Occurrences and Permissive Areas for Other Occurrences in the Islamic Republic of Mauritania

1 Summary

Previous PRISM reports discuss a variety of industrial minerals. Gypsum, phosphate, salt, stone, sulfur, and ilmenite command the majority of the attention in the earlier geologic reports. (Ilmenite is evaluated in a separate U.S. Geological Survey report in the current study). Asbestos, arsenic, barite, fluorite, and kaolin are listed in indices (occurrence datasets) as potential mineral resources (Marsh and Anderson, 2015), but previous reports do not elaborate on their development potential. Beryl, described herein with the discussions of pegmatites, is also listed in indices of potential mineral resources, but has not been described in terms of its industrial mineral potential. Short discussions on the potential for cement (carbonate rocks), glass sand, peat, and sillimanite resources are included in this report.

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Conversion Factors

SI to Inch/Pound

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
decimeter (dm)	0.32808	foot (ft)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
	Area	
hectare (ha)	2.471	acre
square meter (m^2)	0.0002471	acre
square kilometer (km^2)	0.3861	square mile (mi^2)
	Volume	
cubic kilometer (km^3)	0.2399	cubic mile (mi^3)
	Mass	
gram (g)	0.03527	ounce, avoirdupois (oz)
kilogram (kg)	2.205	pound avoirdupois (lb)
megagram (Mg)	1.102	ton, short (2,000 lb)
megagram (Mg)	0.9842	ton, long (2,240 lb)
metric ton per day	1.102	ton per day (ton/d)
megagram per day (Mg/d)	1.102	ton per day (ton/d)
metric ton per year	1.102	ton per year (ton/yr)
	Pressure	
kilopascal (kPa)	0.009869	atmosphere, standard (atm)
kilopascal (kPa)	0.01	bar
	Energy	
joule (J)	0.0000002	kilowatt hour (kWh)

ppm, parts per million; ppb, parts per billion; Ma, millions of years before present; m.y., millions of years; Ga, billions of years before present; 1 micron or micrometer (µor µm) = 1 × 10^{-6} meters; Tesla (T) = the field intensity generating 1 Newton of force per ampere (A) of current per meter of conductor

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

°F=(1.8×°C)+32

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

°C=(°F-32)/1.8

Coordinate information is referenced to the World Geodetic System (WGS 84)

Acronyms

AMT	Audio-magnetotelluric
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
AVIRIS	Airborne Visible/Infrared Imaging Spectrometer
BIF	Banded iron formation
BLEG	Bulk leach extractable gold
BGS	British Geological Survey
BRGM	Bureau de Recherches Géologiques et Minières (Mauritania)
BUMIFOM	The Bureau Minier de la France d'Outre-Mer
CAMP	Central Atlantic Magmatic Province
CGIAR-CSI	Consultative Group on International Agricultural Research-Consortium for Spatial Information
DEM	Digital Elevation Model
DMG	Direction des Mines et de la Géologie
EMPA	Electron Microprobe Analysis
EM	Electromagnetic (geophysical survey)
EOS	Earth Observing System
eU	Equivalent uranium
GGISA	General Gold International
GIF	Granular iron formation
GIFOV	Ground instantaneous field of view
GIS	Geographic Information System
HIF	High grade hematitic iron ores
IHS	Intensity/Hue/Saturation
IAEA	International Atomic Energy Agency
IOCG	Iron oxide copper-gold deposit
IP	Induced polarization (geophysical survey)
IRM	Islamic Republic of Mauritania
JICA	Japan International Cooperation Agency
JORC	Joint Ore Reserves Committee (Australasian)
LIP	Large Igneous Province
LREE	Light rare-earth element
METI	Ministry of Economy, Trade and Industry (Japan)
MICUMA	Société de Mines de Cuivre de Mauritanie
MORB	Mid-ocean ridge basalt
E-MORB	Enriched mid-ocean ridge basalt
N-MORB	Slightly enriched mid-ocean ridge basalt
T-MORB	Transitional mid-ocean ridge basalt
Moz	Million ounces
MVT	Mississippi Valley-type deposits
NASA	United States National Aeronautics and Space Administration
NLAPS	National Landsat Archive Processing System
OMRG	Mauritanian Office for Geological Research
ONUDI	(UNIDO) United Nations Industrial Development Organization

PRISM	Projet de Renforcement Institutionnel du Secteur Minier
PGE	Platinum-group elements
RC	Reverse circulation drilling
REE	Rare earth element
RGB	Red-green-blue color schema
RTP	Reduced-to-pole
SARL	Société à responsabilité limitée
SEDEX	Sedimentary exhalative deposits
SNIM	Société National Industrielle et Minière (Mauritania)
SP	Self potential (geophysical survey)
SRTM	Shuttle Radar Topography Mission
SWIR	Shortwave infrared
TISZ	Tacarat-Inemmaudene Shear Zone
TM	Landsat Thematic Mapper
UN	United Nations
UNDP	United Nations Development Program
US	United States
USA	United States of America
USGS	United States Geological Survey
UTM	Universal Transverse Mercator projection
VHMS	Volcanic-hosted massive sulfide
VisNIR	Visible near-infrared spectroscopy
VLF	Very low frequency (geophysical survey)
VMS	Volcanogenic massive sulfide deposit
WDS	Wavelength-dispersive spectroscopy
WGS	World Geodetic System

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Phase V, Deliverable 89

By William H. Langer[1]

3 Introduction

Industrial minerals typically are valued for their physical or chemical properties. Some are valued as sources of specific elements or compounds, such as salt for chemical feedstock or phosphate rock for agricultural applications. Others are valued for a combination of physical properties, such as color, texture, the presence of flaws and irregularities, and fracture spacing in dimension stone. Yet others are valued for a combination of physical and chemical properties, such as low hardness and particle shape, plus low levels of metals and other impurities in pharmaceutical gypsum. Subtle differences in the physical or chemical properties of industrial minerals can vary the performance of minerals from one deposit to the other.

Some industrial minerals, such as dimension stone, have a low unit value and are bulky, and obtain value by being located near sources of transportation to the market. Others, such as the rare earth elements, have a high unit value and can be located farther from the market. These variables require a thorough understanding of an industrial mineral and the markets it serves.

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3.1 Overview of Mauritania's Industrial Mineral Potential

The dataset of mineral deposits in the Islamic Republic of Mauritania (Marsh, and Anderson, 2015) lists 164 occurrences of 13 industrial minerals in Mauritania (table 3.1, fig. 3.1, and Langer and Horton, 2015). Figure 3.2 displays the areas in Mauritania with some predicted potential for an industrial mineral deposit, which are discussed in this report and shown in more detail in Langer and Horton (2015).

Six industrial minerals command the majority of the attention in the earlier geologic reports—dimension stone, gypsum, ilmenite, phosphate, salt, and sulfur. Dimension stone has become a commodity of interest in the last decade and is produced commercially in small quantities. Gypsum is produced for use in plaster and cement. Salt has been exploited by artisanal methods for centuries. Ilmenite, phosphate, and sulfur have been the subject of detailed studies but are not produced in significant quantities. Four industrial minerals—asbestos, arsenic, barite, fluorite, and kaolin—are discussed in the geologic descriptions of the area (sections 5.1 to 5.5), and are shown as indices of potential mineral resources (Marsh and Anderson, 2015), but the reports do not elaborate on their potentials for use as industrial minerals. Beryllium minerals (principally beryl) are included in the discussion of pegmatites (section 5.6), but also have not been described in terms of their industrial mineral potential. Short discussions of cement, glass sand, peat, and sillimanite (section 5.7) are included, although none of these commodities were previously described as potential mineral resources.

There are conflicting summaries of industrial minerals in earlier geologic reports (compare discussions in Marot and others, 2003; Pitfield and others, 2004; and Salpeteur, 2005). Most prior studies agree that there is potential for a range of industrial mineral commodities, but there is inadequate information regarding the existence of resources of adequate size, grade and quality. Furthermore, most potential mineral occurrences are located distant from market areas, and many areas lack transport infrastructure. However, with additional resource characterization and a favorable market analysis (which includes transportation methods and costs), some industrial mineral resources may become classified as commercially viable.

Table 3.1. Industrial minerals occurrences reported in Marsh and Anderson (2015).

Commodity	Number of Occurrences
Arsenic	1
Asbestos	1
Barite	19
Beryl (Beryllium minerals)	11
Dimension stone (marble, granite, ornamental)	58
Fluorite	3
Gemstone	12
Gypsum	1
Kaolin	2
Peat	23
Phosphate	29
Salt	3
Sulfur	1
Total	**164**

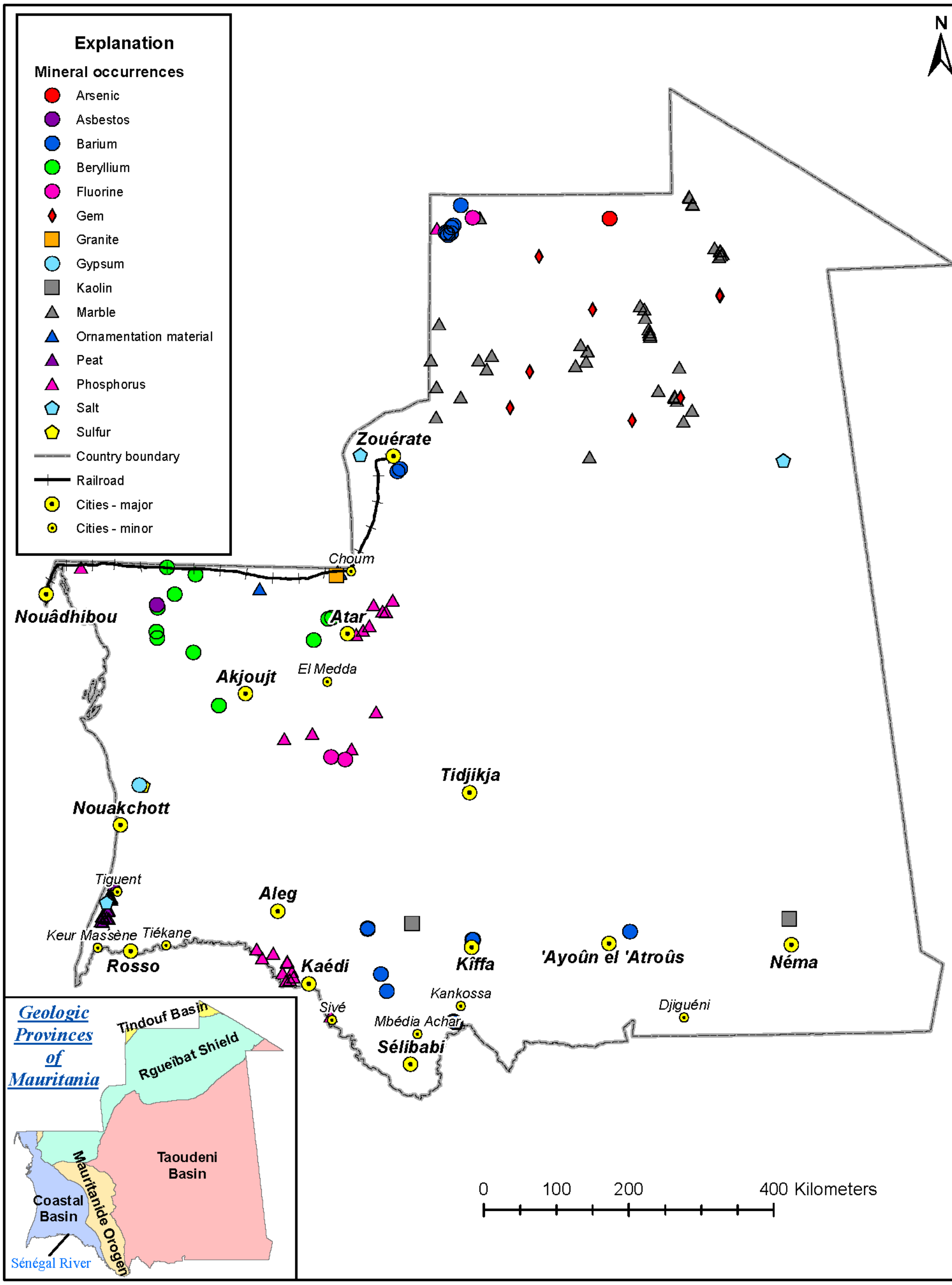

Figure 3.1. Index map showing the locations of 164 reported occurrences of industrial mineral deposits in Mauritania. Data from Marsh and Anderson (2015).

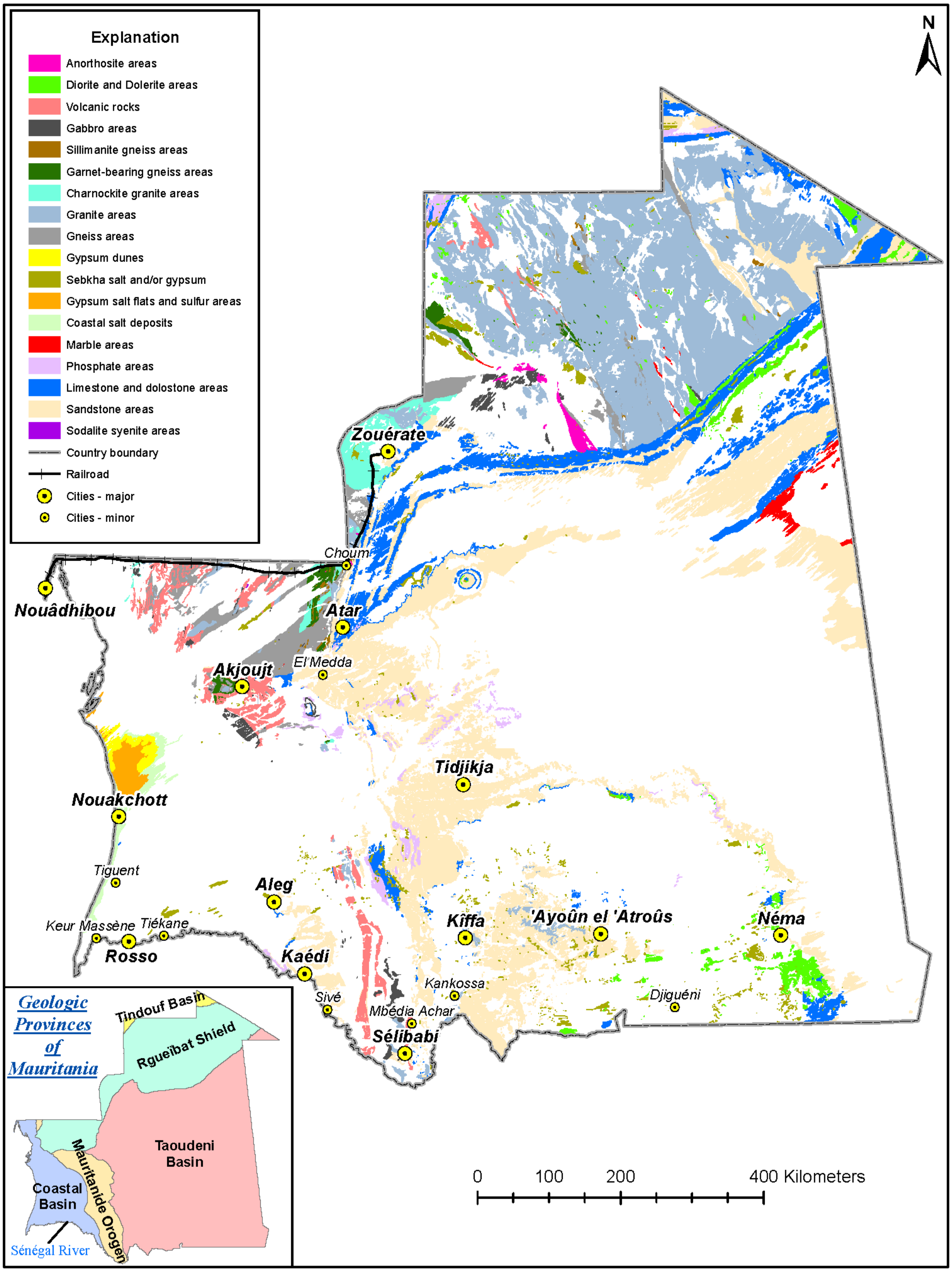

Figure 3.2. Index map showing the geologic areas in Mauritania deemed permissive for occurrences of industrial mineral deposits (shown in more detail in Langer and Horton, 2015).

3.2 Sources of information

This report is a compilation and distillation of existing information contained in the referenced reports listed below. More expanded discussions can be found in those reports.

3.2.1 Geologic Factors

The geologic descriptions of industrial minerals and figures used in this report were copied verbatim, paraphrased, or rewritten from translations of PRISM reports by Marot and others (2003), Pitfield and others (2004), and Salpeteur (2005).

3.2.2 Marketing Factors

The marketing factors described in this report were derived from Kogel and others (2006) and from U.S. Geological Survey (2012).

4 Industrial Minerals of Primary Interest

4.1 Dimension Stone

4.1.1 Geologic Factors

The railway that extends from Nouâdhibou to the iron mines near Zouérate (fig. 3.2) provides easy access to the coast and opens up the railway corridor area for development of high-bulk industrial minerals, such as dimension stone (also referred to as building or ornamental stone), for an export market. A small number of trial quarries into bare rock hillsides have been opened by SNIM as far as 20 km south of the railway to determine the potential of the basement lithologies as building stones. The largest of the quarries is into a sodalite-bearing syenite (fig. 4.1). Blocks with faces up to several meters in length have been removed by splitting the rock using closely spaced vertical drill holes, transported from this quarry to the railway where they are stockpiled. There are also smaller quarries in garnetiferous quartzofeldspathic gneisses (fig. 4.2) and pyroxene-bearing gneisses, as well as into the syenite. There is considerable potential for the production of facing stones because of the large number of rocky hillsides close to the railway. Facing stones are cut slabs of rock used to cover and decorate building exteriors.

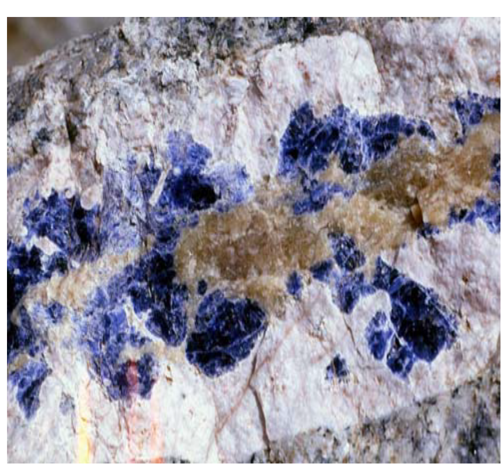

Figure 4.1. Sodalite-syenite from quarry located at Gleibat Tleiha (fig. 3.1), Tasiast-Tijirit Terrane (from Pitfield and others, 2004).

Near Atar (fig. 3.2), stromatolitic limestones and the more massive sandstones in the lower parts of the Taoudeni Basin (fig. 3.2) are used as building stones. Small stockpiles of limestone are periodically collected and transported to Atar and to Nouakchott. The Formation de Beddamez is comparatively soft feldspathic sandstone, typically fine-grained and well bedded, and is worked as blockstone for use in numerous villages, such as El Medda (fig. 3.2). These operations are typically small in scale and work shallow excavations. North of Atar, dolomitic limestone in the Formation de Ksar Torchane has been used for building stone.

A variety of rock types in Mauritania may be suitable for dimension stone (building stone, ornamental stone); these include anorthosite, sodalite syenite, and gabbro, granites, gneiss and garnet-bearing gneiss, and marble (fig. 3.2 and Langer and Horton, 2015). The special qualities of any particular rock type as an ornamental stone are difficult to describe and quantify, and can be best explained as being "in the eye of the beholder". General considerations for dimension stone and decorative stone characteristics are described by Mead and Austin (2006) and Austin and others (2006). In addition to special visual and structural qualities of the rock, the economics of dimension and decorative stone are controlled strongly by transportation methods and associated costs from quarry to market.

Figure 4.2. Dimension stone quarry in garnetiferous granulite on the north side of the railway line at Choum (from Pitfield and others, 2004).

4.1.2 Marketing Factors

Dimension stone can be defined as natural rock material quarried for the purpose of obtaining blocks or slabs that meet specifications as to size (width, length, and thickness) and shape. Color, grain texture and pattern, and surface finish of the stone are normal requirements. Durability (essentially based on mineral composition and hardness and past performance), strength, and the ability of the stone to take a polish are other important selection criteria.

Although there was probably some small-scale production in the majority of the world's nations, production of dimension stone was officially reported in about 26 countries. The top five producing countries since 2000 have been, in descending order by tonnage, China, India, Italy, Iran, and Spain. These countries have accounted for about 60 percent of the world's production during the last decade. Dimension stone sales and usage generally follow trends of the general economy, to which the construction markets are highly linked and affected.

4.2 Aggregate

4.2.1 Geologic Factors

Aggregate is simply sand, gravel, and crushed stone used in an endless variety of construction and infrastructure applications. As a result, in most countries the annual value of production of aggregate exceeds the metals, even though the metals typically well exceed the price of aggregate materials on a tonnage basis. To constantly repair and maintain, update and expand, and modernize transportation systems, buildings, and infrastructure in general, a consistent and quality supply of aggregate is a must in all countries.

Mauritania has a diverse variety of rock types that could be crushed and used as sources of aggregate. The list of rock types that may be potential aggregate sources is similar to the list for decorative and dimension stones—granites, anorthosite and gabbro, and gneiss (fig. 3.2 and Langer and Horton, 2015). Other rock types that can be added to this list are carbonate rocks (limestone and dolomite), and extrusive and intrusive volcanic rocks (fig. 3.2). The extrusive volcanic rocks are most likely only suitable for road base and other applications that allow for lower-strength, high-silica content material.

4.2.2 Marketing Factors

A detailed discussion and marketing analyses of aggregate sources in Mauritania is beyond the scope of this study. The permissive tracts shown in figure 3.2 and Langer (2012) provide a good starting point for identifying potential bedrock sources of crushed stone on a local or regional basis as supplies are needed for a particular area and construction project.

As with dimension and decorative stone, transportation costs from the mine site to the site of usage is a significant (often main) factor in selecting the site for an aggregate operation. The many factors that should be considered in selecting aggregate, including physical properties of quality aggregate, are described in detail in Langer (2011) with U.S. examples.

4.3 Gypsum

4.3.1 Geologic Factors

Possibly one of the largest gypsum deposits in the world occurs at Sebkha N'Drhamcha (figure 4.3—the blue area with diagonal ruled pattern), between 50 and 100 km north-northeast of Nouakchott, located close to the coastal road north of Nouakchott. Two types of deposits occur in the area: bedded deposits and dune deposits.

The bedded gypsum deposits outcrop chiefly along the eastern flank of the Sebkha N'Drhmacha. Available information suggests that the thickness of the deposits is greatest towards the center of the sabkha, decreasing to the west and north. There are several hundred million tonnes of resources of which about 140 million tonnes are proven reserves.

Resources identified in dune deposits occur about 55 km from the highway that connects Nouakchott and Akjoujt (fig. 3.2), accessed by the coastal highway. Limited sampling of these deposits, which are secondary accumulations in both active and indurated dunes, indicated grades of 92–93 percent $CaSO_4{\cdot}2H_2O$ with about 1.5 percent SiO_2 (Pitfield and others, 2004). A provisional resource estimate suggested about 2 Mt in one small area of dunes.

Extraction rates have been as high as 100,000 tonnes per year for plaster and cement production. The favorable location close to the main road, together with the high grades and limited thickness of overburden, make these deposits attractive for exploitation. They are capable of meeting Mauritania's domestic requirements for plaster and derived products.

4.3.2 Marketing Factors

Gypsum occurs throughout the world and global gypsum resources are enormous. More than 90 countries produce gypsum worldwide (table 4.3). Costs for mining gypsum are relatively low, but energy-intensive processing and ultimate end use add significant cost and value to the products made from the gypsum. Commonly, the main factors that make deposits commercially valuable are proximity to market area, work force, utilities, and an inexpensive method of transportation of the raw materials or the finished products.

Worldwide, the predominant use of gypsum is in the manufacture of construction plasters and portland cement. In North America, the predominant use of gypsum is in wallboard panels. However, increased wallboard plant construction in China and Thailand indicates that Asia, with billions of potential consumers, could become one of the world's leading gypsum wallboard markets. Elsewhere, the recognition of the convenience and economy of wallboard as a building material, and increased wallboard production capacity in Central America, Europe, India, and South America suggests increased demand for gypsum in the future. There is no foreseeable shortage of gypsum resources in the world. More than 400 products can be manufactured from gypsum using specialized methods of calcination and formulation with additives. Applications include ground gypsum in agriculture; specialized plaster products in art and statuary; intricate cast architectural detail; medical applications; and fast-setting, high-strength construction products.

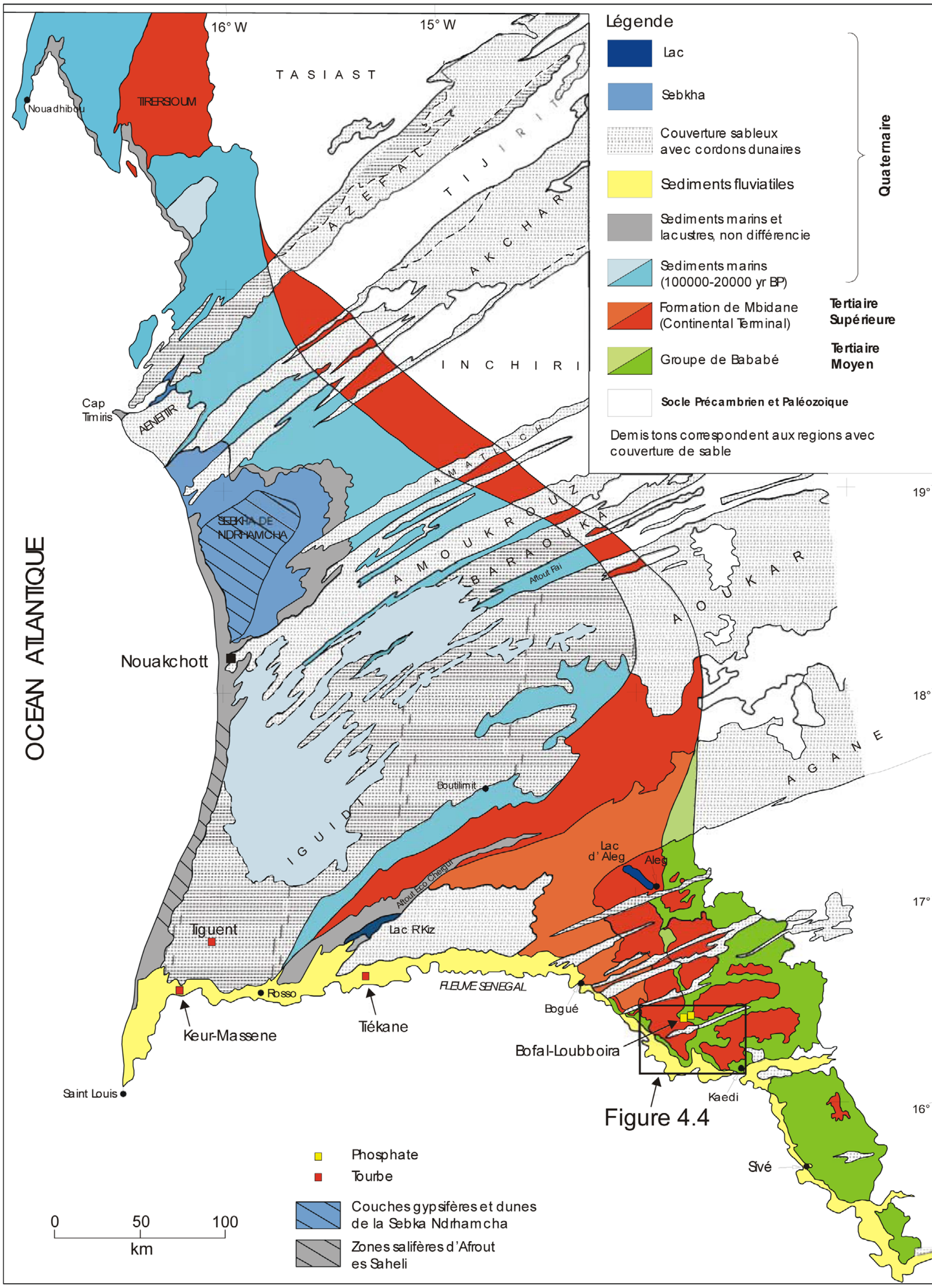

Figure 4.3. Geology of the Mauritanian Coastal Basin with locations of principal mineral indices (from Pitfield and others, 2004).

Table 4.3. World gypsum production, 2010–2011. Source: USGS, Mineral commodities summaries, 2012. Available at http://minerals.usgs.gov/minerals/pubs/commodity/gypsum/.

Country	Production x 1,000 tonnes	
	2010	2011
United States	8,840	9,400
Canada	2,717	2,300
China	47,000	47,000
Mexico	3,560	3,500
Thailand	8,500	8,500
Japan	5,700	5,700
Australia	3,500	3,500
France	2,300	2,300
India	2,650	2,700
Russia	2,900	2,900
Egypt	2,400	2,400
Iran	13,000	13,000
Spain	12,500	13,000
Other countries	31,400	31,800
Total	**147,000**	**148,000**

4.4 Phosphate

4.4.1 Geologic Factors

4.4.1.1 Phosphate Deposits in the Bofal Formation

Phosphate deposits occur in outcrops of the Eocene-age Bofal Formation along the northern bank of the Senegal River, about 300 km from the coast (fig. 3.1). Two deposits have been extensively studied: 1) one deposit at the village of Bofal, and 2) another deposit at Loubboira (fig. 4.4).

Reserves at Bofal are 70 Mt with an average thickness of 1.7 m, an average grade of 21 percent P_2O_5 and an average overburden of 8 m. In comparison, Loubboira has 29 Mt of reserves with an average thickness of 2 m, an average grade of 19 percent P_2O_5 and an average overburden of 7 m. These resources are open to the north at Bofal and to the southeast at Loubboira; total probable reserves could exceed 100 Mt. Resources were also identified in several other zones to the south, which are less well known than the two principal areas. The deposits at Bofal and Loubboira are essentially a continuation of those that occur 100 km to the southeast in Senegal at Matam, where a deposit exceeding 36 Mt at 28.7 percent P_2O_5 has been identified. On the opposite bank of the river from Matam at Sivé, in Mauritania, resources of about 150,000 tonnes have been identified, where phosphate rock beds average 26–28 percent P_2O_5. These deposits have some potential for use as direct application fertilizer and it is reported that local farmers are extracting phosphate rock for this purpose. The phosphate beds in the Bofal Formation are relatively undisturbed and gently dipping. The grade of the concentrate recovered in metallurgical testing is high, 35–36 percent P_2O_5, while the contents of impurities and potentially hazardous elements (U, As, Cd) are low. The thickness of the overburden cover gives a stripping ratio of 6.6:1 for open-pit mining.

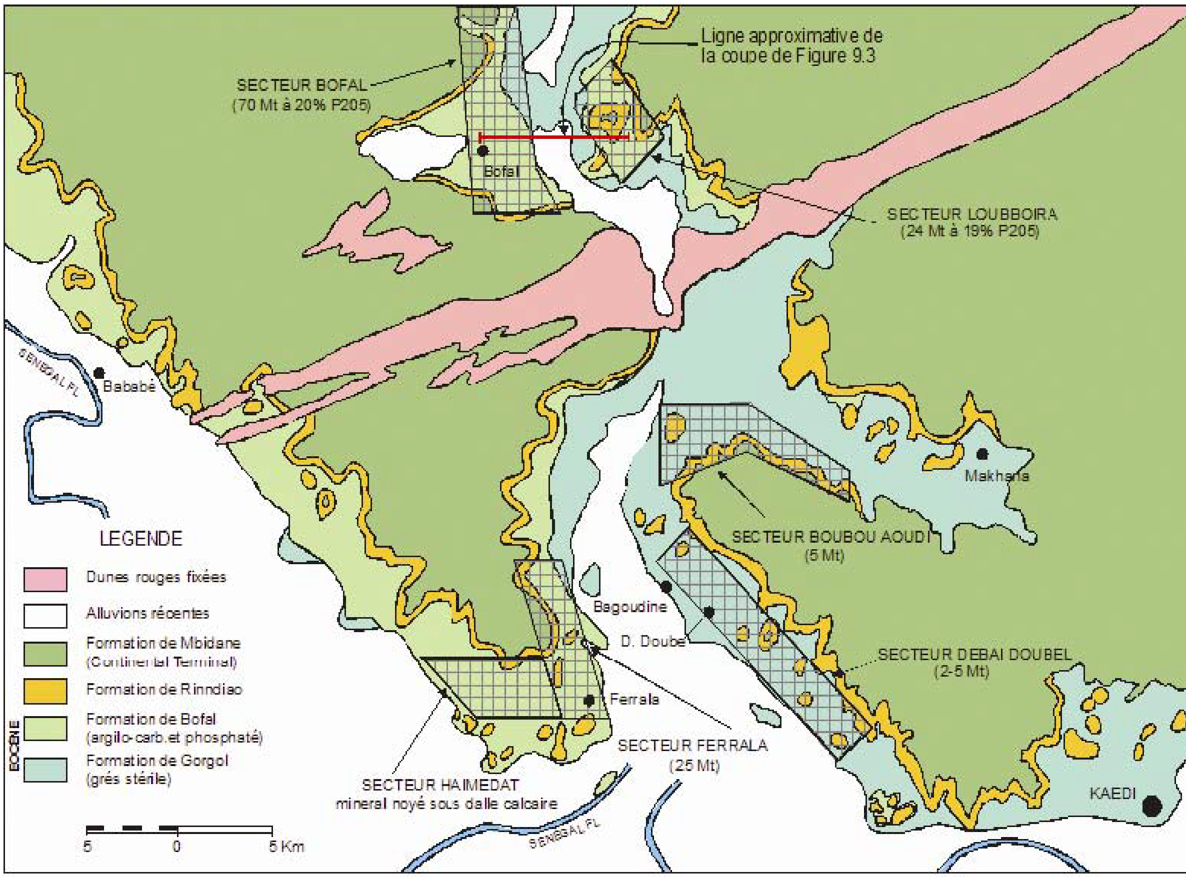

Figure 4.4. The distribution of sedimentary phosphate resources in the district of Bofal-Loubboira, located to the west of Kaedi (from Pitfield and others, 2004).

A pre-feasibility study of a 2 million tonnes of concentrate/year operation concluded that the mineralization was particularly suited to the manufacture of phosphoric acid and fertilizers and was comparable with products derived from Togo and Morocco. However, the study also concluded that transportation costs (by road, Senegal River, railway or pipeline) would be too high to make exploitation economically viable. A modern feasibility study is required to fully evaluate the potential for mining at these locations.

4.4.1.2 Phosphates in the Taoudeni Basin

Occurrences of sedimentary phosphate deposits are widespread in the Taoudeni Basin (fig. 3.1 and Langer and Horton, 2015) although available information suggests that they are generally small and low grade. Furthermore their remote locations, far away from areas of farming and food production, means that they are unlikely to be high-priority exploration targets. The host rocks are chiefly in the upper Neoproterozoic Groups. The potential of these strata to host economic phosphate deposits remains unknown, but the Neoproterozoic–Lower Cambrian time period is an important depositional interval—significant resources of this age occur in several countries in West Africa. Extensive investigations would be required to determine the potential of the phosphate occurrences in the Taoudeni Basin.

Phosphate occurrences east and northeast of Atar (fig. 3.1) were identified in Marsh and Anderson (2015). Phosphate occurs in two types of geologic settings: (1) conglomerates that contain cobbles of phosphate rock, and (2) apatite-bearing quartzite. Neither deposit type is likely to represent economic deposits.

4.4.2 Marketing Factors

There is strong competition for phosphate production in the region. Morocco has the world's largest phosphate reserve base which consists of high-grade, easy-to-process deposits. The first phosphate rock was produced there in 1922 and since then production has steadily increased to the current level of more than 25 Mt per year (table 4.4).

Neighboring Senegal is blessed with extensive reserves of exceptionally high quality phosphate. Phosphate from Taïba, which has been mined since 1960, is famous around the world.

Phosphate rock is used primarily for production of wet-process phosphoric acid for fertilizer applications. The remainder was used in the manufacture of animal feed supplements, for direct application to soils, and for elemental phosphorus production.

Increasing energy costs make it increasingly less economical for global shipments of phosphate rock. The recent trend is toward processing of phosphate rock where it is mined. Nevertheless, phosphate and its products are globally-traded commodities. If processed phosphates are included in export figures, about 60 percent of the phosphate is exported. Morocco and the United States account for nearly half of these exports, with the United States exporting more than 50 percent and Morocco more than 95 percent of their respective phosphate production.

Table 4.4. World phosphate production, 2010–2011. Source: USGS, Mineral commodities summaries, 2012. Available at http://minerals.usgs.gov/minerals/pubs/commodity/phosphate_rock/.

Country	P_2O_5 content x 1,000 tonnnes	
	2010	2011
United States	25,800	28,400
China	68,000	72,000
Morocco and West Sahara	25,800	27,000
Russia	11,000	11,000
Tunisia	7,600	5,000
Brazil	5,700	6,200
Jordan	6,000	6,200
Egypt	6,000	6,000
Israel	3,140	3,200
Syria	3,000	3,100
South Africa	2,500	2,500
Australia	2,600	2,700
Other countries	5,500	5,500
Total	**181,000**	**191,000**

4.5 Salt

4.5.1 Geologic Factors

Significant resources of salt occur in the area of L'Aftout es Saheli, which is located along the coast to the south of Nouakchott immediately north of the Senegal River valley. On the eastern side of the L'Aftout depression, important stratified deposits occur at N'Teret and Twidermi in isolated depressions among the marginal dune belt (Langer and Horton, 2015).

The most important area is la saline de N'Teret in southwestern Mauritania (fig. 3.1), which has been exploited by artisanal workers on a small scale since 1845. The salt layers occur in an area about 590 by 630 m in size. The deposit comprises 8 beds of salt. The most accessible, four uppermost beds, each less than 20 cm thick, are more or less worked out. The fifth bed, known as the Sikha el Beïda or Sikhat el Fahl, is a thin, high-quality bed and is the most important economic deposit in the area. It is composed of up to 40 cm of compact high-quality salt. During 1975, the British Geological Survey reported reserves of approximately 150,000 tonnes, and reported that at least two-thirds of this resource has been worked out. The seventh bed, Zrewila, is about 25 cm thick and can only be exploited at the end of the dry season when the water level is at its lowest. The basal bed, Lehreicha, up to 25 cm thick, is difficult to exploit by traditional methods. Production records show that at least 125,000 tonnes of salt were produced by workings between 1934 and 1960 through skilled manual labor (in contrast to machinery). In the 1950s, production varied between 6,000 and 9,000 tonnes per year. It became difficult to maintain production as the deeper beds were exploited.

The deposit at la saline de Twidermi, about 4 km northeast of N'Teret, occupies an area of about 11 hectare (ha). A single 30-cm-thick grayish bed of salt occurs at about 80–85 cm below ground. This bed has been exploited sporadically. Reserves amount to tens of thousands of tonnes.

Another source of small-scale production is la saline d'El Bokharia, located about 10 km southeast of N'Teret. Here a thin bed of salt, about 3 cm thick, occurs as a superficial crust extending over an area of 45 ha. This crust is extracted, dried, and milled. Another deposit of similar type occurs at la saline de Lemzewid, about 30–35 km to the south-southwest. Here the resource comprises a superficial bed of friable salt as much as 5–6 cm thick. Exploitation in this area is sporadic and is influenced by the level of the water table in the area.

Due to the climate and the presence along the coast of elongate depressions at levels below those of occasional marine incursions, there is the potential for many saline marshes, especially in the Nouakchott district. However, no modern resource estimates have been published nor details of recent investigations.

Two historic sites of rock salt production are known in northern Mauritania: (1) The saltworks of Idjil (fig. 3.1) are mined using artisanal methods, which supplies the Nouakchott markets. The salt deposits occupy an area greater than 50 km^2. The top two meters contain ten layers of salt (maximum thickness of 20 cm), interstratified with black clays. The dimensions of the rock salt resources combined with frequent flooding of the area makes the deposits suitable for artisanal mining techniques. (2) Exploitation at the small deposit of Tinioulig (fig. 3.1 and Langer and Horton, 2015) was abandoned at the beginning of the 20th century.

4.5.2 Marketing Factors

Salt deposits or solutions are found in virtually every country in the world. Although the world contains abundant reserves of salt, the location and size of the deposits in relation to the location and size of the salt markets are important factors to consider when developing commercial operations.

Most countries possess some form of salt production capability (table 4.5). Production levels commonly are set to meet domestic demand requirements, although additional quantities may be available for export. Domestic and world consumption of salt will grow proportional to the rise of population and the gross domestic product of countries. The world will continue to mine, harvest, process, transport, and sell salt among neighboring countries. New deposits will be developed that will compete with existing facilities, and the facilities offering a high-quality product with low production and transportation costs will be the leaders of the world salt industry.

Table 4.5. World salt production, 2010–2011. Source: USGS, Mineral commodities summaries, 2012. Available at http://minerals.usgs.gov/minerals/pubs/commodity/salt/.

Country	Production x 1,000 tonnes	
	2010	2011
United States	43,300	44,000
China	62,750	65,000
Germany	19,100	20,000
India	17,000	18,000
Canada	10,537	11,000
Australia	11,968	13,000
Pakistan	11,000	11,000
Bahamas	10,000	10,000
Chile	8,400	9,000
Mexico	8,431	8,800
Brazil	7,020	7,000
France	6,100	6,000
United Kingdom	5,800	5,800
Ukraine	5,400	5,500
Spain	4,350	4,400
Turkey	4,000	4,000
Poland	3,520	4,000
Netherlands	5,000	5,000
Other countries	36,300	38,500
Total	**280,000**	**290,000**

4.6 Sulfur

4.6.1 Geologic Factors

The main occurrence of sulfur in Mauritania is located at Cuprit near the eastern margin of the Sebkha N'Drhamcha, about 5 km west of the main Nouakchott-Akjoujt road and about 60 km northeast of Nouakchott (figs. 3.1 and 3.2; Langer and Horton, 2015). Elemental sulfur is primarily located in gypsum and black marls at concentrations in the range 1.02–12.10 percent (Salpeteur, 2005).

The sulfur at Cuprit most commonly occurs as nodules, pale yellow in color, with an average diameter of about 1 cm. They are irregularly distributed horizontally and vertically, but generally sulfur nodules occur in thin layers about 10 cm thick. In some sectors, the sulfur occurs as thin, mm-scale coatings within the banded gypsiferous marls that overlie black marls. Sulfur also occurs widely throughout the sequence as finely disseminated grains and coarser blebs. Locally cm-scale lenses enriched in disseminated sulfur occur in the upper part of the black marls. Sulfur is most abundant in two horizons; in both cases the sulfur is concentrated in thin layers separated by barren intervals. The sulfur-bearing beds are sub-horizontal and covered by barren cover that varies in thickness to as much as about 2.5 m. These beds have been traced over a distance of 7 km in a northeast–southwest direction. However, the most extensive sulfur-mineralized zone has an area of about 2 km^2 with an average thickness of 0.4 m and an average grade of 1 percent. The richest zone, with an average S content of 2.6 percent and an average thickness is 0.36 m, occupies an area of 0.7 km^2. The deposits contain an estimated reserve of 9,195 tonnes of sulfur at an average grade of 0.98 percent S and an average thickness of 0.39 m. (Information in this paragraph from Salpeteur, 2005).

The dispersed occurrence of the sulfur nodules, combined with the low grade and the narrow thickness of the sulfur-bearing horizons, reduces the potential economic viability for sulfur in this area. Further drilling in the zones of favorable stratigraphy may be justified under certain circumstances, but should normally be assigned a low priority.

The gypsum salt flats within the Sebkha N'Drhamcha, north of Nouakchott, represent another potential source of sulfur. While native sulfur is less common than the nearby deposits at Cuprit, sulfur may be obtained as a product of gypsum processing.

4.6.2 Marketing Factors

Worldwide, compliance with environmental regulations contributed to increased sulfur recovery; however, decreased production in the United States affected global output. Estimated worldwide production of native sulfur has increased slightly (table 4.6). The global sulfur industry is divided into two sectors—discretionary and nondiscretionary. In the discretionary sector, the mining of sulfur or pyrites is the sole objective. At present, sulfur can be economically mined from very few deposits. In the nondiscretionary sector, sulfur or sulfuric acid is recovered as a byproduct, with the quantity of output subject to demand for the primary product and the environmental regulations mandating sulfur removal from the finished products and emissions. Most of the nondiscretionary sulfur that is currently produced comes from natural gas and petroleum deposits, and is often referred to as recovered sulfur. Non-discretionary sources of sulfur represent 89.5 percent of the worldwide sulfur production.

Table 4.6. Sulfur production for the top 11 sulfur-producing countries during 2010–2011. Source: USGS, Mineral commodities summaries, 2012. Available at http://minerals.usgs.gov/minerals/pubs/commodity/sulfur/.

[*Estimated values for 2011]

Country	Production x 1,000 tonnes	
	2010	2011*
China	9,600	9,600
United States	9,070	8,800
Canada	7,255	7,100
Russia	7,070	7,100
Germany	3,905	3,700
Saudi Arabia	3,300	3,300
Japan	3,292	3,100
Kazakhstan	2,000	2,700
Mexico	1,810	1,800
Iran	1,780	1,800
United Arab Emirates	1,763	1,800
World total	**68,100**	**69,000**

5 Industrial Minerals of Secondary Interest

Five industrial minerals—asbestos, arsenic, barite, fluorite, and kaolin—are discussed in geologic descriptions of the area, and are shown in mineral resource datasets of potential mineral resources (Marsh and Anderson, 2015), but earlier reports do not elaborate on their potentials for use as industrial minerals. The mineral beryl is included in the discussion of pegmatites and has been listed previously as a potential mineral resource, but it has not been described in terms of its industrial mineral potential. Discussions of most of the minerals of secondary interest in this report are limited to market factors. The exception is that this report also provides a brief description of elements of potential economic interest associated with pegmatites.

5.1 Asbestos

One reported occurrence of chrysotile asbestos (Knefissat Nord) occurs in an ultramafic rock in the western Rgueíbat Shield (fig. 3.1; Langer and Horton, 2015).

5.1.1 Marketing Factors

World production of asbestos was estimated to be 2 Mt in 2011. Russia continued to be the leading producer of asbestos, followed by China, Brazil, Kazakhstan, and Canada. These countries accounted for 99 percent of the world asbestos production in 2011. Legal actions and adverse publicity on asbestos have adversely affected asbestos markets. World consumption declined from an estimated 4.84 Mt in 1980 to about 1.83 Mt in 2000. Although a few countries have increased or maintained their production, consumption has declined significantly in most countries. This trend is expected to continue because of increased pressure to reduce or ban asbestos usage in major consuming countries. Consumption can be expected to decline as substitutes and alternative products gain favor and as additional countries enact bans on the use of asbestos. Specialized applications for asbestos, particularly for matrix-based products, will probably remain.

5.2 Arsenic

One non-ferrous occurrence of arsenic (Bir Bou Agba) is reported within the Rgueíbat Shield region in northern Mauritania (fig. 3.1) Langer and Horton, 2015).

5.2.1 Marketing Factors

During 2006, commercial grade As_2O_3 was recovered from the processing of nonferrous metal ores or concentrates in 14 countries. China remained the world's leading producer of As_2O_3, followed by Chile and Peru. In addition to production from nonferrous metal ores, arsenic was also obtained as a byproduct of gold mining in China.

The elimination of the use of arsenic as a wood preservative for certain wood products at yearend 2003 has led to a decline in consumption of arsenic and in a decline in As_2O_3 production in China. High-purity arsenic is expected to continue to be used by the electronics industry for Ga-As-based semiconductors for automotive uses, military and space applications, solar cells, and telecommunications equipment. World sources of arsenic, as As_2O_3 and arsenic metal available from nonferrous metal processing, are expected to be sufficient to meet projected needs.

5.3 Barite

Nineteen occurrences of barite are reported, which are located in the Rgueïbat Shield (including Tindouf Basin), the Mauritanides Orogenic Belt (Orogen), and the Taoudeni Basin (fig. 3.1; Langer and Horton, 2015). Barite resources of Mauritania occur in bedded sedimentary layers and in epithermal barite-fluorite veins associated with alkaline intrusions (Marsh and Anderson, 2015).

5.3.1 Marketing Factors

China is the leading exporter of barite and for many years has been the low-cost supplier in world markets. However, from December 2003 to December 2005, the published import price of Chinese barite increased by about 33 percent, and prices for barite from the other major exporting countries (India and Morocco) rose similarly. The factors that pushed up Chinese prices were high ocean freight costs, port congestion, problems with internal freight logistics, and the lowering of the tax rebate on barite exports.

The use of barite has been historically tied to the oil industry because more than 95 percent of the produced barite is used in that market. The other 5 percent of the barite market is for industrial uses, mostly the automotive-related industry.

5.4 Fluorite

Three occurrences of fluorite are reported to occur in the Rgueíbat Shield and the Mauritanides Orogenic Belt (fig. 3.1; Langer and Horton, 2015).

5.4.1 Marketing factors

World mines production of fluorspar in 2011 was about 6.2 Mt, and world reserves (measured as 100 percent CaF_2) are estimated at 240 Mt. The leading producers, in descending order, were China, Mexico, Mongolia, and South Africa.

Fluorocarbon demand is expected to experience a negative growth rate in Europe and Japan due to concerns about the global warming potential of HFCs. Demand for acid-grade fluorspar is expected to remain strong in North America because of growing demand for fluorocarbon-base refrigerants. The continued growth in the fluoropolymer and fluoroelastomers markets also will contribute due to strong demand. Export prices for acidspar will remain high for other major exporting countries, such as Mexico, Mongolia, and South Africa, although significantly lower than Chinese prices. Despite some recent production capacity increases by non-Chinese producers, there is still insufficient capacity to replace the supplies from China, so consumers will be forced to pay the higher Chinese prices. Additional fluorspar supplies are expected to occur from capacity increases in Mongolia (although infrastructure problems make exporting to the West difficult) and possibly supplies from South Africa and Vietnam.

5.5 Kaolin

Two occurrences of kaolin are reported in Mauritania: one occurrence each in the Mauritanides Orogenic Belt (Oudelemguil 1) and the southern Taoudeni Basin (Dhar Nema 3) (fig. 3.1; Langer and Horton, 2015).

5.5.1 Marketing Factors

Kaolin is a global industrial mineral primarily used as a pigment to improve the appearance and functionality of paper and paint; as a functional filler for rubber and plastic; as a ceramic raw material; and as a component for refractory, brick, and fiberglass products. Other lower volume uses for kaolin include chemical manufacture, civil engineering, agricultural applications, and some pharmaceuticals.

The limited availability of suitable raw material, extremely competitive market conditions, and the technological complexity of kaolin processing and kaolin product functionality creates a high barrier of entry into kaolin production.

5.6 Mineral Resources Associated with Pegmatites

Occurrences of beryl and rare earth elements (REE) were identified in the indices database (Marsh and Anderson, 2015). These industrial mineral commodities are commonly associated with granitic pegmatites. The potential for REE resources in Mauritania are addressed in a separate USGS report (Taylor and Giles, 2015).

Granitic pegmatites are potential sources of a wide range of rare metals, including Li, Rb, Cs, Be, Ga, Sc, Y, REE, Sn, Nb, Ta, U, Th, Zr and Hf. The coarse grain size and high purity of their industrial mineral components makes them attractive exploration targets that might support small-scale extraction of both ore and industrial minerals. They also have potential as sources of semi-precious stones, such as rose quartz, aquamarine and tourmaline.

Although pegmatites are widespread in the Rgueïbat Shield, all of the larger known bodies have been examined in the past and, on account of their small size, they are unlikely to support commercial mining activities.

There are several quartzofeldspathic pegmatites in the Choum–Rag El Abiod terrane (Key and others, 2008). Individual veins are up to about 1 m in thickness, with tightly folded early veins and less deformed later veins.

Several occurrences of Li- and Be-bearing pegmatites were discovered in the western part of the Rgueïbat Shield (fig. 3.1). Earlier investigations concluded that their economic potential was low with a few occurrences containing a few tens of tonnes of beryl and in other cases small amounts, up to a maximum of 10 tonnes, of spodumene or lepidolite. The pegmatites are found in three areas of the Rgueïbat Shield (Key and others, 2008): in the Chami greenstone belt; in the Sebkhet Nich area of the Tijirit Greenstone Belt; and in the northeastern part of the Amsaga Complex about 25–50 km west of Atar.

More than 150 occurrences of beryl-bearing pegmatites were recorded in the Khnefissat area in the northwestern sector of the Chami greenstone belt, about 100 km east of Nouâdhibou. Here the veins are generally 2–4 m thick and can be traced for several hundred meters. They comprise a network of both horizontal and vertical veins cutting fractured amphibolite. Veins of this type are also found in the Timmimichat, Guetel Khaye, Sineine and Inkebden zones. In addition aplo-pegmatitic and albitite veins may accompany the more common quartzofeldspathic pegmatites. They form veins closely associated with the more typical pegmatites and are generally a few tens of cm wide and may be up to a maximum of 100 m in length. They are commonly highly deformed and unmineralized. Albitites, however, which are very closely associated with the aplites, are often highly mineralized. They comprise relatively undeformed veins of quartz, albite, spessartine and muscovite. Beryl is a widespread component, while spodumene, lepidolite and columbo-tantalite may be present locally.

In the terrane between Choum and Rag el Abiod (Key and others, 2008), the most important pegmatites occur within the metagabbro massif of Iguilid. In this area 15 veins are known, of which 12 have been reported to contain beryl. The veins attain a maximum thickness of 5 m and can be traced along strike for up to about 100 m, dipping eastwards or sometimes horizontal. They comprise quartz, feldspar, muscovite, tourmaline and garnet with sporadic crystals of blue beryl up to a few tens of cm in size.

5.6.1 Beryl

Eleven occurrences of beryl are reported within the western part of the Rgueíbat Shield (fig. 3.1; Marsh and Anderson, 2015).

5.6.1.1 Marketing Factors

Beryllium has been recovered from small deposits in many countries throughout the world, but production has been sporadic. The world beryllium industry is rather concentrated presently, limited to a single active beryllium producer located in Utah, United States; this mine supplies almost all United States domestic and most worldwide consumption.

World consumption of beryllium is forecast to increase by about 2 percent per year during the short to medium term. Existing production and stockpiles are expected to be sufficient to meet demand.

5.7 Other Industrial Minerals

5.7.1 Carbonate Rocks

The Taoudeni basin within Mauritania (fig. 3.2) contains limestones and dolomites that can be processed according to their degree of purity for several industrial uses, such as cement manufacture, refractory brick, steel metallurgy, and magnesian lime soil amendment.

Karstified dolomites located in Sfariat, halfway between Zouérate and Bir Moghreïn, may have industrial uses, either as lime or ornamental stone.

There is a possibility that locally extensive Quaternary shell deposits might provide a suitable source of raw material for cement manufacture, as they do in other parts of the world. However, high-purity limestone, chalk, and marble are usually the most important sources of CaO for this purpose because they occur in large deposits sufficient to meet demand over a long time period, which is required to justify the major capital investment required for a cement plant. Other sources of silica, alumina and iron oxides are usually supplied by locally quarried mudstone or clay. Gypsum is another critical component of cement. Because all of these ingredients may be present in the Coastal Basin, considerable further study is required to identify adequate quantities close to infrastructure and capable of providing carbonate rock feed of consistent purity and specification to the plant in the long term. Furthermore, cement manufacture is a highly energy intensive process and results in the production of large amounts of carbon dioxide. These factors also require close consideration.

5.7.2 Clay

North of Atar, shales in the Formation de Ksar Torchane have been worked as a source of clay for brick manufacture.

5.7.3 Glass Sand

Wind erosion of sandstones can yield relatively pure white sands that are appropriate for the manufacture of glass. Large white quartz seams (for example, at Guelb Naad), could also be processed as glass sand.

5.7.4 Peat

About 3,313,273 m^3 of peat reserves have been discovered in southwest Mauritania at Tiguent, Keur-Massène and in the Tiékane area (figs. 3.3 and 4.3) in a network of depressions and ancient channels situated between aeolian dunes over a 5,000 km^2 area. The thickness of the peat deposits varies between 0.2–5.0 m, with an average of 0.8 m. Overburden thicknesses are in the range 0–2.0 m. The peat is sometimes wet and contains salt. It is also clayey and locally sandy.

In order to establish the economic viability of the peat deposits identified to date in south-western Mauritania (fig. 3.1 and Langer and Horton, 2015), considerable further analytical work is a priority in order to establish key physical and chemical parameters, such as calorific value, pH, the contents of S, C, N and a wide range of other elements. Another key technical challenge concerns the removal of sand from the peat for which the optimum technology has not yet been determined in Mauritania.

5.7.5 Talc

Talc lenses are common in the serpentinites of the Mbédia Achar area (fig. 3.2), but the talc is often impure.

5.7.6 Trona

Several playas were mapped on the 1:500 000–scale geologic map sheets of Néma, Djigueni, and Kankossa. These playas may be a source of trona (potassium salt) and other evaporite minerals.

5.7.7 Sillimanite Gneiss

Sillimanite gneiss outcrops: (1) about 25 km southwest of Atar along the highway to Akjoujt and (2) along the railway about 80 km north from Atar (fig. 3.2 and Langer and Horton, 2015).

In addition to potential uses as aggregate and dimension stone, these gneisses contain the aluminum-silicate mineral sillimanite, which can have other industrial uses. Due to its high alumina content (>60 percent Al_2O_3) and high melting point (>1,100° C), sillimanite is valued in the production of refractories and ceramic products. Significant deposits of sillimanite minerals are currently mined in South Africa, India, France and China.

Conclusions

Five industrial minerals are described in detail in the PRISM geologic reports—dimension stone, gypsum, phosphate, salt, and sulfur. Three industrial minerals appear to have significant potential as commodities for export: (1) The railway line to the iron mines opens large areas for dimension stone for export markets, providing easy transport access to the coast. (2) The gypsum resources at Sebkha N'Drhamcha (figs. 3.1 and 3.2) are potentially very large. (3) Significant deposits of phosphate exist in the Mauritanian Coastal Plain. However, there is inadequate information regarding the size, grade, and quality of these resources to make definitive opinions on their development and economic value. Most of the potential mineral occurrences are located distant from market areas. The potential industrial mineral resources will require additional local-scale geologic investigation, detailed resource characterization, and market analysis before they can become deemed viable economic commodities.

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