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

Mineral Potential Tracts for Shoreline Ti-Zr Placer Deposits:

Phase V, Deliverable 85

By Georges Beaudoin

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Multiple spellings are used in various literatures, and may be reflected in the text.

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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Mineral Potential Tracts for Shoreline Ti-Zr Placer Deposits

Summary

Shoreline Ti-Zr placer deposits in Mauritania are hosted by littoral dune and beach sand on the Atlantic coast. Potential mineral tracts for Shoreline Ti-Zr placer deposits in Mauritania comprise areas along the coast covered by Quaternary sediments. Definition of Shoreline Ti-Zr placer resources in Mauritania is inadequate because their volume is poorly constrained above the water table only, and the TiO_2 grade or percentage of ilmenite in the bulk sand is converted to an equivalent tonnage of ilmenite, thereby ignoring more valuable minerals such as rutile, leucoxene and zircon, in the resource inventory. Zircon, in particular is the principal ore mineral in the Grande Côte Zircon project in Senegal. Zircon is reported to be abundant in the Mauritanian deposits, thereby increasing the inferred value of potential deposits.

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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
EC	Electrical conductivity
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
LOR	Lower limit of reporting
LREE	Light rare-earth element
METI	Ministry of Economy, Trade and Industry (Japan)
MICUMA	Société des 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
SIMS	Secondary Ionization Mass Spectrometry
SNIM	Société National Industrielle et Minière (Mauritania)
SP	Self potential (geophysical survey)
SRTM	Shuttle Radar Topography Mission
SWIR	Shortwave infrared
TDS	Total dissolved solids
TIMS	Thermal Ionization Mass Spectrometry
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

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

Mineral Potential Tracts for Shoreline Ti-Zr Placer Deposits:

Phase V, Deliverable 85

By Georges Beaudoin[1]

Introduction

Shoreline placer Ti deposits are composed of ilmenite, rutile, zircon, monazite, and magnetite in well-sorted, fine- to medium-grained sand in coastal dunes, beaches and inlets. In addition to titanium, zirconium, in particular, and rare earth elements (REE) have become a major source of value in shoreline placer deposits. Shoreline placer deposits form mostly on tropical beaches around the world (fig. 1), and consist of dark sand layers rich in heavy minerals that are resistant to mechanical abrasion and chemical weathering. According to Hamilton (1995), shoreline placer deposits supply approximately 80 percent of the world's rutile production, 25 percent of ilmenite, 100 percent of zircon, and 50 percent of both monazite and xenotime.

Shoreline Ti Placer Deposits in Mauritania

In Mauritania, Quaternary sediments with potential for shoreline placer Ti-Zr deposits are present in the Permian to Recent Senegal-Mauritania sedimentary coastal basin. Quaternary sediments were deposited during the Tafaritian, Aïoujian, and Inchirian (> 30 Ka) marine transgressions. The Ogolian sequence (10–24 Ka) formed eolian dunes over the coastal basin and continental interior, recording dry conditions during the Wurmian glacial event (Gunn and others, 2004). The Nouakchottian (Tchadian 10–5.2 Ka, Deynoux and others, 2001) is the last transgression that records more humid conditions with clay and shell sands deposits (Gunn and others, 2004). The last, the Tafolian regression (< 4 Ka), is characterized by a littoral dune system that formed sabkha gypsum and clay deposits. The shoreline Ti-Zr placer deposits are hosted by the Tafolian littoral dunes and by active and ancient beach deposits (fig. 2).

[1]Département de Géologie et de Génie Géologique, 1065 avenue de la Médecine, Québec (Québec) Canada G1V A6.

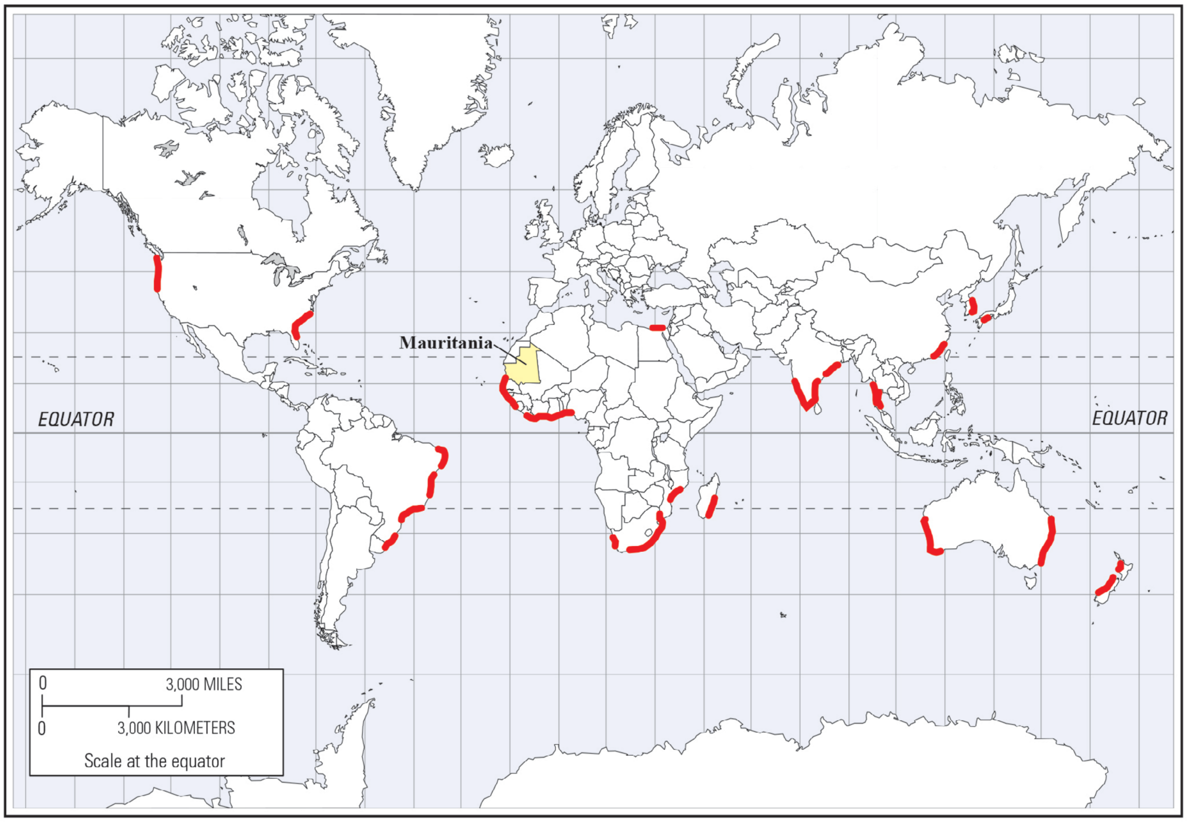

Figure 1. Worldwide distribution of shoreline Ti-Zr placer deposits (modified from Hamilton, 1995).

According to Gunn and others (2004) citing Blanchot (1975), the Quaternary formations of Mauritania have been prospected for their content of heavy minerals by the Bureau de Recherche Géologique et Minière (BRGM) between 1959 and 1963. This work identified shoreline placer Ti deposits that were then subjected to further mineralogical and geophysical studies (fig. 3). From north to south, three sectors with shoreline placer Ti have been identified. The first, south of Nouadhibou, from Pointe Minou to Cap el Sass, hosts approximately 2.8 Mm^3 (million cubic meters) of sand containing the equivalent of 120,000 t ilmenite (fig. 3). The second, near El Msid north of Nouakchott, hosts approximately 2.6 Mm^3 of sand with the equivalent of 242.6 t ilmenite (fig. 3). The third sector, south of Nouakchott and near Legouichichi, contains approximately 0.495 Mm^3 of sand with the equivalent of 30,000 t of ilmenite (fig. 3). Blanchot (1975) notes that the auger drill holes used to estimate grade and tonnage did not penetrate beneath the water table so it is possible that additional resources could exist at depth. Gunn and others (2004) citing previous ONUDI studies, indicated that radiometric methods are efficient to locate and estimate the grade of heavy minerals in sand.

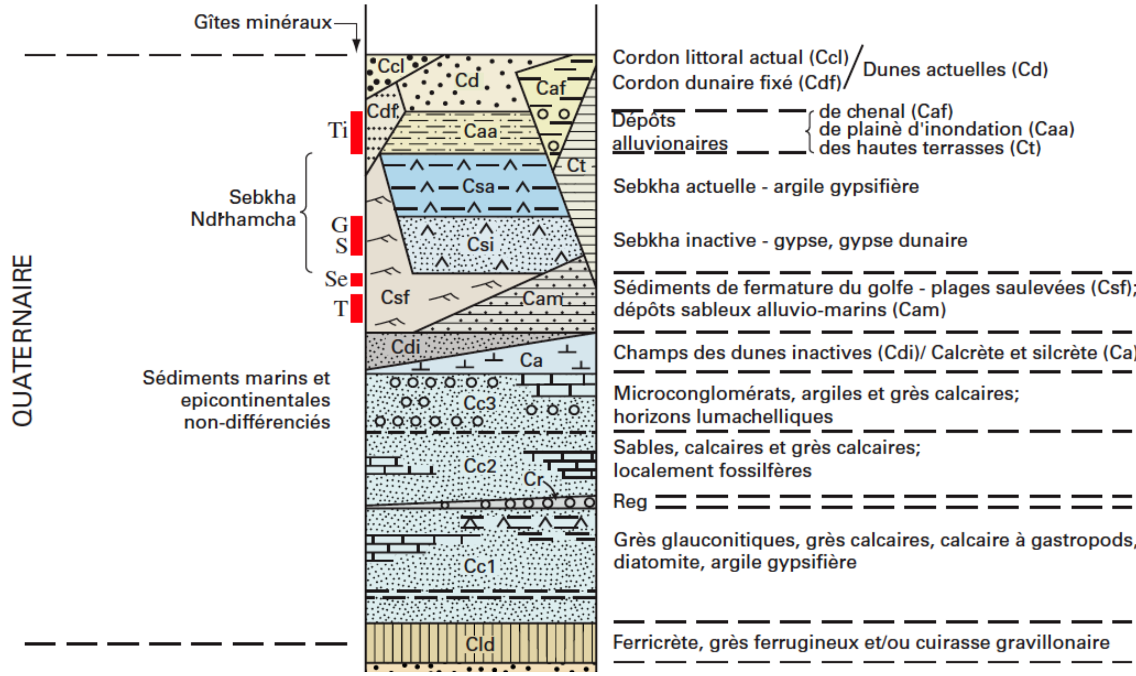

Figure 2. Stratigraphic position of shoreline placer Ti deposits in Mauritania. Abbreviations: G, gypsum; S,: sulfur; Se, salt; T, peat. Modified from Gunn and others (2004).

For this study, shoreline Ti-Zr placers were described and sampled near El Msid, north of Nouakchott (figs. 3 and 4). At El Msid, dark sands form layers in crescent-shaped dunes that are partly reworked by the action of waves in the active beach (figs. 3 and 4). The top part of the dunes concentrate heavy minerals by the removal of light minerals by the wind, also called deflation lag. The dunes are being slowly reworked by the transgressive, active beach where heavy minerals are redistributed by wave action, which typically yields low-angle cross-bedding within a sand layer (fig. 4). Hand-panned heavy mineral concentrates were prepared on site. Table 1 displays the bulk concentration of important chemical elements from the heavy mineral concentrates. It should be noted that the concentrate composition is affected by the field concentration process. The Fe/Ti ratio is constant at 1.16 to 1.44, similar to slightly above the ilmenite ratio Fe/Ti of 1.17, therefore suggesting most Ti is hosted by ilmenite in the concentrates. The Ti content ranges from 11.6 to 18.2 weight percent which corresponds to 36.8 to 57.7 weight percent of ilmenite, assuming all Ti is in the oxide. The heavy mineral concentrates contain 2.8 to 6.4 weight percent Zr which corresponds to 5.7 to 6.8 weight percent zircon. Th ranges from 356 to 831 ppm whereas U has low variance from 58 to 77 ppm. The low Th and U coupled with low phosphorus content suggest that the abundance of monazite and xenotime is also low. Assuming that all Zr and U are hosted by zircon, the maximum U content of zircon is calculated to be between 10 and 18 ppm. The Zr/Hf ratio ranges from 24 to 38, which is typical for crustal zircons (Clairborne and others, 2006). Several REE have high concentrations in the bulk concentrate, most notably La (≤1,070 ppm), Nd (≤770 ppm), and Y (≤372 ppm).

Table 1. Composition chimique des concentrés de minéraux lourds, El Msid, Mauritanie.

No. Lab	No. Échan	Fe %	Ti %	P %	Dy ppm	Ga ppm	Gd ppm	Ge ppm	Hf ppm	Ho ppm	La ppm	Lu ppm	Nb ppm
C-318115	GB07RIM03B	16.7	11.6	0.06	50.5	32	45.2	8	1180	11.8	399	9.92	441
C-318116	GB07RIM04B	21.6	18.2	0.10	54.1	20	70.9	5	1870	12.3	824	11	531
C-318117	GB07RIM05B	20.8	16.6	0.13	49.7	21	79.4	4	1470	10.1	1070	8.37	419
C-318118	GB07RIM07C	20.2	17.4	0.14	47.5	17	73.3	3	1660	10.1	997	8.56	428
		Nd ppm	**Pr ppm**	**Sm ppm**	**Tb ppm**	**Th ppm**	**Tl ppm**	**Tm ppm**	**U ppm**	**V ppm**	**Y ppm**	**Yb ppm**	**Zr ppm**
C-318115	GB07RIM03B	312	91.2	55.5	7.53	356	<0.5	7.53	57.6	482	358	61.4	28400
C-318116	GB07RIM04B	612	181	96.7	9.58	706	<0.5	7.47	77.1	598	372	67.3	60300
C-318117	GB07RIM05B	770	223	120	9.99	831	<0.5	5.8	67.4	564	296	52.4	55400
C-318118	GB07RIM07C	735	216	112	9.2	825	<0.5	5.81	71.8	548	281	52.5	63800

Mineralogical studies in three areas (Jreida, Bloauokh, and Tanit) indicate that the black sand deposits contain an average composition of 26.5 weight percent rutile, 22.5 weight percent ilmenite, 11.8 weight percent garnet, 10.2 weight percent zircon, 7 weight percent epidote and 22 weight percent other minerals (Zagortchev and others, 1978; Gunn and others, 2004). These results are similar to values estimated from the bulk composition of the concentrates panned on site (table 1).

It is instructive to compare the Mauritanian deposits to those being developed in Senegal. Mineral Deposits Ltd (Australia) is planning to mine a mineral resource of 1.03 Gt (Gigatonne = 1 x 109 tonnes) of sand with 1.7 weight percent heavy minerals (using a 1.5 weight percent heavy mineral cut-off grade) in the 50-km-long Grande Côte Zircon deposit on the coast of Senegal, between Dakar and St-Louis (www.mineraldeposits.com.au). Heavy minerals are composed of ilmenite (~66–74 percent), leucoxene (~4–7 percent), rutile (~1–3 percent) and zircon (~7–11 percent). The zircon has low levels of impurities such that it can marketed as “high-quality” zircon, thus constituting the most desirable economic mineral in the deposit. Rutile and leucoxene also will produce revenue whereas the abundant ilmenite will probably be stockpiled until its value allows for profitable sale. It is instructive to note that the information at hand so far suggests the shoreline placer Ti-Zr deposits of Mauritania also have a high content of zircon, with low U content, such that it could be of the higher quality which yields higher revenue.

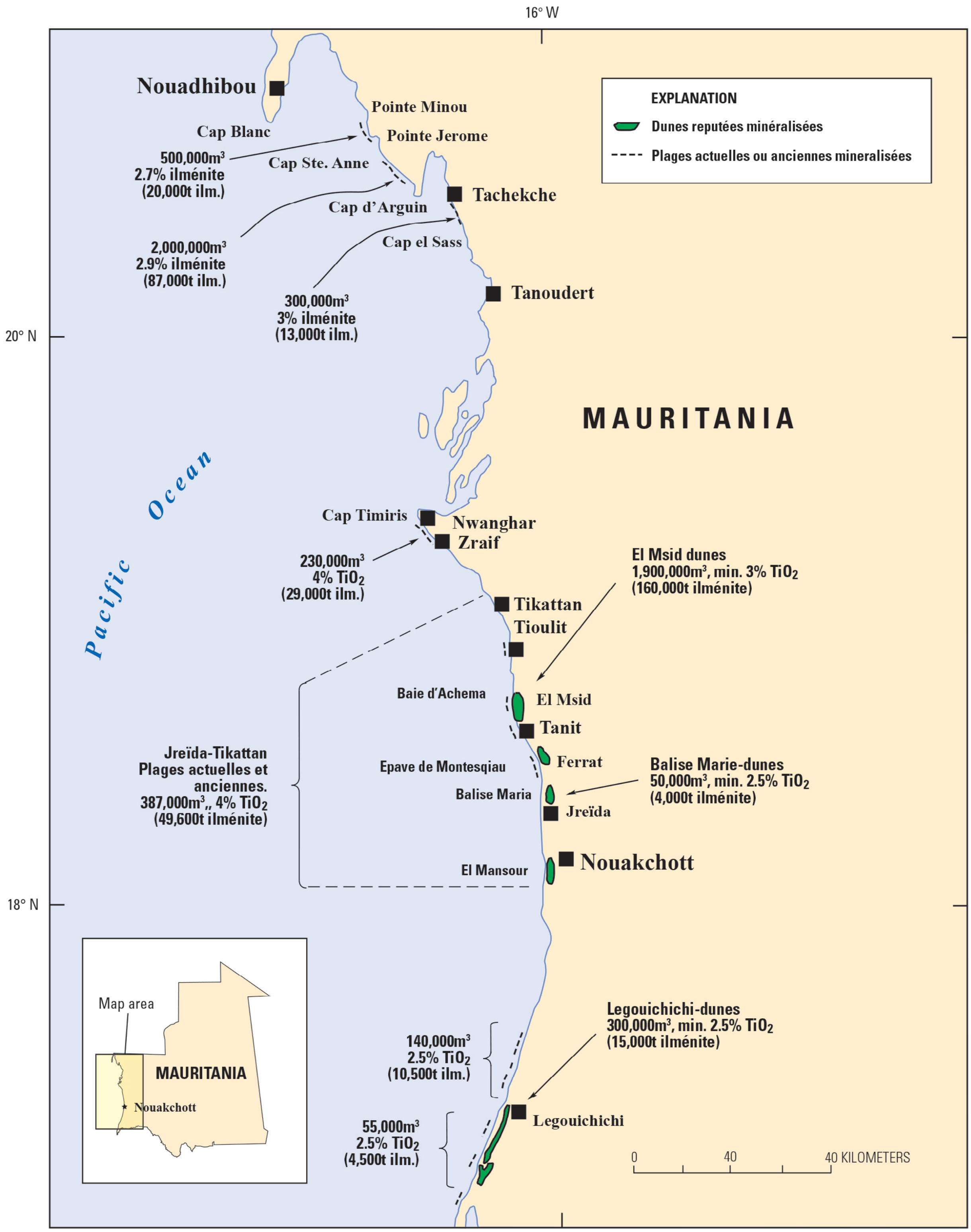

Figure 3. Location of shoreline placer Ti deposits as defined by the BRGM (Blanchot, 1975, as modified by Gunn and others, 2004).

Figure 4. Top, crescent-shape dunes with dark sand layer on top, the dune at the bottom right of the figure is partly reworked by the active beach. Middle, rippled upper surface of a sand dune where dark-colored heavy minerals concentrate by deflation lag. Bottom, layer of dark-colored heavy minerals in the active beach. USGS photos.

Permissive Mineral Tracts for Shoreline Ti-Zr Placers

The permissive mineral tracts for Shoreline Ti-Zr placer deposits are defined by location of the littoral dune sand (cordon dunaire fixé: cdf), reworked dune sand (sable dunaire ancien remanié: cdi), active or inactive beach sand (cordon littoral actuel: ccl), eolian sand dunes (dunes: cd), and gulf closure sediments and raised beach sand (sédiments de fermeture du golfe—plages soulevées: csf). Considering the dispersion of shoreline placer Ti deposits along the shore for most of Mauritania's Atlantic coast, the permissive mineral tracts for Shoreline Ti-Zr placer comprises all the Mauritanian coast covered by these sand units (Appendix A).

Conclusion

1. The littoral dune sand, reworked dune sand, and recent or inactive beach sand of the coast of Mauritania have demonstrated Shoreline Ti-Zr placer deposits. These beach and dune sands constitute the permissive mineral tract for this deposit type in Mauritania (fig. 5);
2. Reliable resource estimates for the Shoreline Ti-Zr placer deposits do not exist, as the historical figures are not constrained with factors such as a cut-off grade;
3. The Shoreline Ti-Zr placer deposits are currently defined on the basis of their Ti or ilmenite content, whereas the more abundant, and higher value, minerals rutile and leucoxene have been potentially overlooked (either because grade is computed from ilmenite or Ti weight percent is converted into ilmenite grade), and the high zircon content has not been taken into consideration.

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Appendix A

Régions de la Mauritanie avec un potentiel pour les gites de titane dans les placers cotiers.

From:

Beaudoin, Georges, and Horton, J.D., 2015, Permissive tracts for shoreline placer titanium deposits in Mauritania (phase V, deliverable 84), , chap. P1 *of* Taylor, C.D., ed., Second projet de renforcement institutionnel du secteur minier de la République Islamique de Mauritanie (PRISM-II): U.S. Geological Survey Open-File Report 2013–1280-P1, 1 pl., http://dx.doi.org/10.3133/ofr20131280/. [In English and French.]

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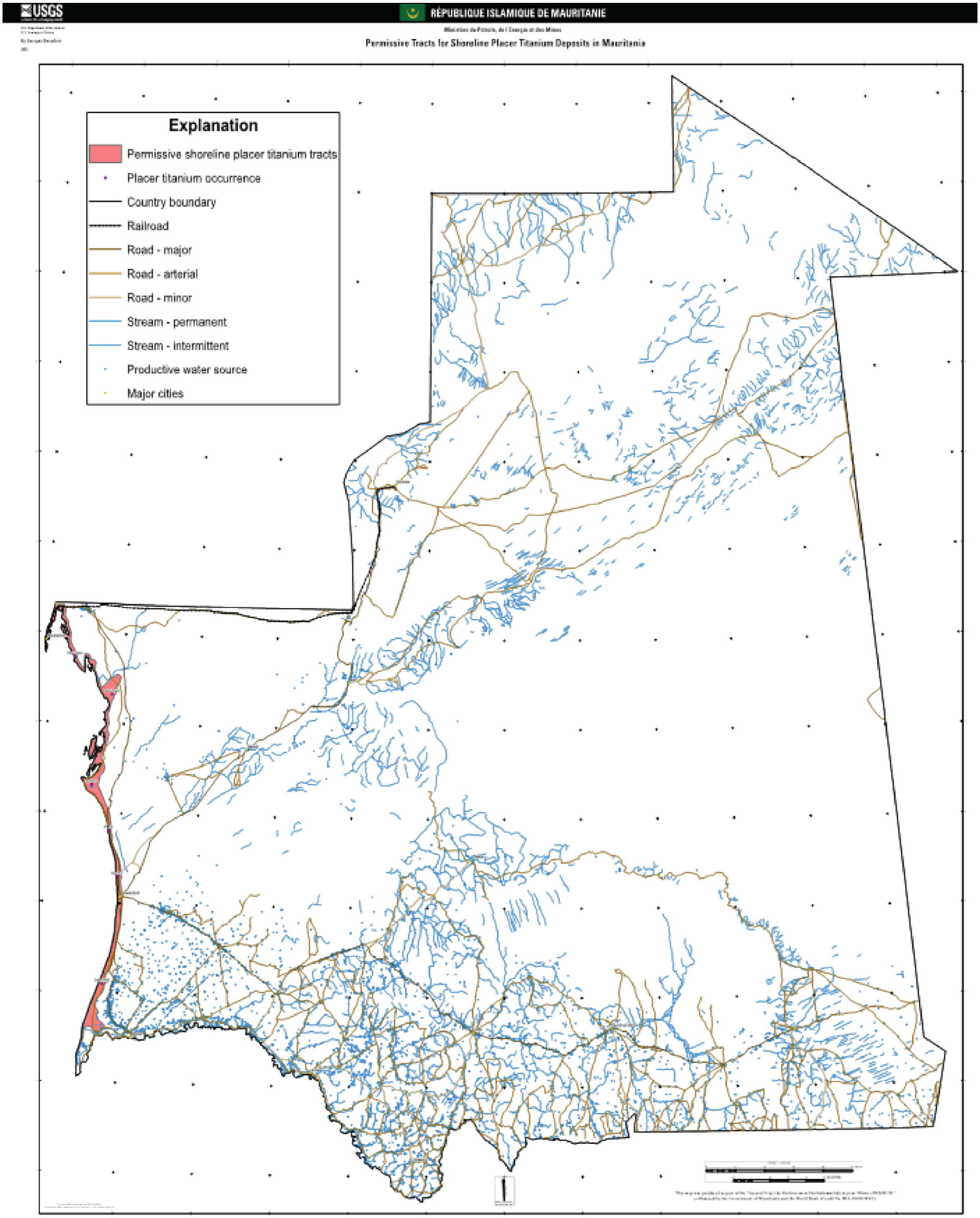
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RÉPUBLIQUE ISLAMIQUE DE MAURITANIE
Permissive Tracts for Shoreline Placer Titanium Deposits in Mauritania
Explanation
Permissive shoreline placer titanium tracts
Placer titanium occurrence
Country boundary
Railroad
Road - major
Road - arterial
Road - minor
Stream - permanent
Stream - intermittent
Productive water source
Major cities