Newly verified occurrences of industrial minerals in Belize

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Modern society is characterised by functional infrastructure and sufficient number and variety of materials in the form of various technical goods. All these achievements of civilisation are not only the result of human skills, but their material principles are based on industrial minerals. This group of materials includes a wide range of the natural raw materials which are used in many industries. This includes the raw materials for the manufacture of glass, ceramics or fillers. For other raw materials, new applications are just being developed. These materials are very desirable in the market. Not only are their supplies endless, but they occur very unevenly in the natural deposits and unlike most metals can't be recycled. Due to low production costs in the production of this type of the raw materials, the competition in the global market has significantly increased during recent years. With this growing trend has significantly increased the interest in these materials in developing countries, which is precisely the Central American country of Belize. In the context of the cooperation, project has been verified several economically interesting sources such as ceramic clay, bentonite, feldspar and carbonate materials.

Key words: *industrial minerals, Belize, bentonite, ceramic clays, feldspar raw material, dolomite*

Introduction

Belize is a small country on the eastern coast of Central America. With 22,800 square kilometres of land and population of 340 844 inhabitants, Belize has the lowest population density in Central America. On the north, it borders with Mexico and to the west and south with Guatemala. The formal Head of the State is Queen Elizabeth II., but the real power has the Parliament and the Government that is led by the Prime Minister.

A large part of the Belizean territory comprises a coastal plain; however, in the southeast, the Maya Mountains rise to an altitude of over than 1,000 m. The coast is lined with small islands and coral reefs that constitute a part of the Mesoamerican Barrier Reef System, the largest coral reef in the Western Hemisphere. Its major watercourses are the Belize River and, along the border with Mexico, the Hondo River.

The principal economic sectors are agriculture, tourism and the food industry. Revenues from tourism account one-fifth of the total GDP. The importance of oil extraction has been increasing which has become the most important export item in recent years. Mining and quarrying of other minerals have only a limited scope; mining of gold is also limited and of the industrial minerals here are limestone, dolomite and gravel.

The environmentally friendly utilisation of mineral resources is one of the national priorities. The occurrence of some industrial minerals has been verified during the last decade on the basis of cooperation between Czech and Belizean geologists.

The geological structure of Belize is strongly linked with the tectonic evolution of the Central American region about 80 million years ago (Fig.1). Rifting in the area began during the Late Triassic and continued into the Cenozoic as the Caribbean Plate migrated eastwards. The eastward drift of the Caribbean plate resulted in the dominantly structurally-controlled, major features of Belize: the Maya Mts., offshore atolls surrounded by deep water, and the location of the coral barrier reef (Mazzullo, 2006).

The Belize mainland can be subdivided into three geological provinces: Northern Belize, South-Central and Southern Belize. The Corozal Basin of Northern Belize, north of the Maya Mountains, representing an eastern continuation of the northern Guatemala Petén Basin. The Maya Mountains are part of the South-Central Belize, and Southern Belize contains the Belize basin that borders the Maya Mountains offshore to the east and onshore and offshore to the south, and is continuation of the southern part of the Petén Basin (Aitken et al., 2002; Purdy et al., 2003).

The oldest rocks exposed on the mainland are in the Maya Mountains, the primary source of siliciclastics in the region. The Maya Mountains are the high, rugged core of Belize, composed of Paleozoic igneous, metamorphic, and sedimentary rocks. Silurian to Devonian granites are overlain by Upper Carboniferous to Middle Permian sedimentary, meta-sedimentary and volcanic rocks that, in turn, were deformed and intruded by

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granite during the Triassic. The surrounding flat plains are largely undeformed Jurassic siliciclastics, and Cretaceous to upper Tertiary carbonates with some evaporites, largely limestones that indicate that Belize was covered by a warm, shallow sea during this long period of time. Pleistocene carbonate rocks are present mainly in low-lying areas along the coast and are associated with siliciclastics in the central and southern parts of the country (Mazzulo, 2006; Purdy et al., 2003).

Bentonite clays

In the Cayo District of Western Belize, the Spanish Lookout deposit of bentonite clays was assessed. This site is situated in the south-western area of the Corozal Basin, which extends across northern mainland Belize from the northern boundary of the present day the Maya Mountains to the northern and western borders of Belize (Flores, 1952; Rao & Ramanathan, 1988; Purdy et al., 2003). The Corozal Basin is divided by the northwest trending Hill Bank Fault into two subunits, the western Blue Creek Sub-Basin and the eastern Orange Walk Sub-Basin. The area studied lies in the Blue Creek Sub-Basin, between two important tectonic lines – the Yalbac Fault to the north-west and the Boundary Fault dividing the Maya Block to the south.

The bentonite clays constitute a part of the Miocene Red Bank formation (Cornec, 2003; Belize Fm of Purdy et al., 2003) and are underlain by limestone. The bentonite clays frequently contain various calcareous admixtures and gypsum or silica (chalcedony) intercalations. At Spanish Lookout, this formation reaches a thickness of over 230 m (700 ft, Meerman et al., 2012).

Based on the results of shallow boreholes drilled with a hand-held auger set, proven reserves of overall 649 thousand tonnes of bentonite clay were assessed in the Spanish Lookout deposit (Tvrdý, 2010). However, the raw material potential of the entire area is much greater than that. The content of smectite mineral (montmorillonite of the Na>Ca>K type) ranges from 60 to over 90 wt. %, depending on the sample and the method of determination used. Generally speaking, X-ray diffraction analysis (XRD) provides considerably lower figures than the theoretical content as determined by using methylene blue adsorption (MBA). The MBA values range from 300 to 480 mg/l (averaging 385 mg/l), the cation exchange capacity (CEC) is generally above 50 mol/kg.

The principal impurities that influence the technological parameters are calcite and gypsum. At the same time, however, both of these minerals confer favourable off-white, white to cream colours to the raw material. Most probably these admixtures are responsible for the low gelling and absorptive ability and also for the higher bulk density as already noted by Pickering & Bloodworth (2003).

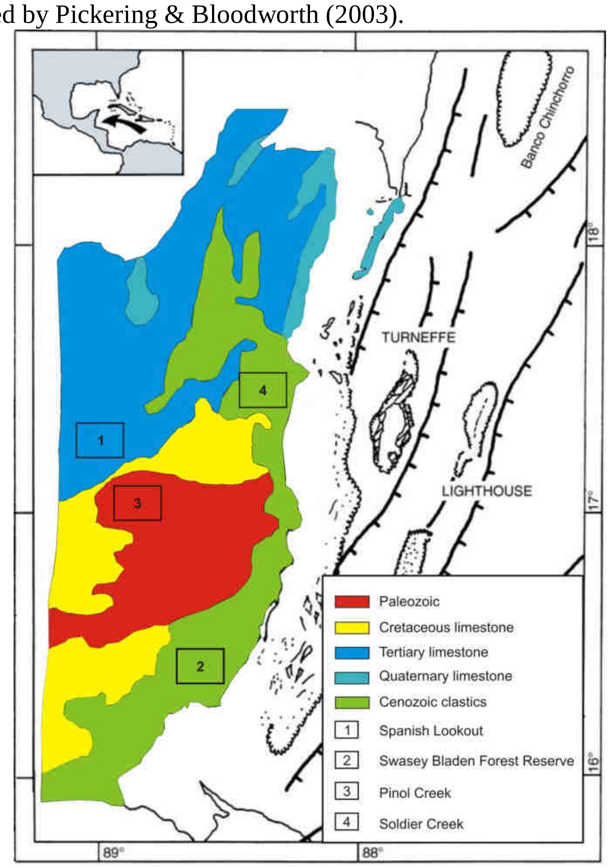

Fig. 1. A simplified geological map of Belize and location of studied area.

When seeking for possibilities for the utilisation of the raw material particular attention should, therefore, be given to:

- Mineral litter for cats and other small animals. Despite the relatively high average weight of 994 grams per litre (ranging between 920-1050 g), the prepared samples (grain size 0.71-5.0 mm) met the rigorous test requirements in accordance with the German methodology (the clumps are solid, free of cracks and its absorbability is usually in the range of 140-180 wt. %).
- The foundry industry. Though it frequently contains an adverse admixture of carbonates and sulphates, the raw material shows a high degree of thermostability (over 54 %), fission strength (over 14 kPa) and binding capacity (over 79 kPa). It will, therefore, be necessary to carry out further technological testing, preferably in the manner of a pilot operation.
- Sealants (for landfills and water reservoirs) and waterproofing systems (e.g. mats, tapes).
- The production of plaster mixes and mortars.
- Pharmaceuticals – the manufacture of creams, pills and other drugs (e.g. products analogous to the "Smecta" preparation made by the IPSEN pharmaceutical group and to commercial food supplements of the Austrian "Schindele's Mineralien" type).
- Agriculture – as an ingredient in feed mixtures or for the reclamation of light sandy soils that are too permeable (e.g. for binding the nutrients in the soil and for moisture retention)
- Beverages – for clarifying wines and ciders, for stabilising beer, for the purification of sugar juice.

To check any specific application of the raw material in one of the above fields, it is necessary to undertake more detailed specialised testing.

Tab. 1. Average chemical composition of the bentonite clay from the Spanish Lookout deposit [wt. %].

	Mean	**Range**
SiO_2	47.8	42.4-55.0
Al_2O_3	16.5	14.0-18.1
Fe_2O_3	3.6	3.1-3.8
TiO_2	0.40	0.36-0.43
CaO	8.0	5.7-13.3
MgO	2.7	2.5-2.9
K_2O	0.6	0.4-0.9
Na_2O	1.3	1.2-1.4
L.O.I.	13.0	11.1-16.0
SO_3	5.9	1.6-9.3
MnO	0.08	0.05-0.21
Cl	0.05	0.01-0.09
Cr_2O_3	0.01	0.01-0.02
As_2O_3	0.01	0.00-0.01

Tab. 2. Average mineralogical composition of the bentonite clay from the Spanish Lookout deposit [wt. %].

Calcite	4	2-14
Gypsum	9	5-17
Muscovite / illite	9	8-11
Kaolinite	4	2-5
Quartz	4	1-8
Anatase	0.3	0.1-0.9
Sanidine	1	0-2
Montmorillonite (X-ray diffraction)	67	51-78
Montmorillonite (methylene blue adsorption)	77	60-96

Fig. 2. Exploratory drilling at the Spanish Lookout deposit using a hand-held Eijkelkamp auger set.

Fig. 3. Spanish Lookout – a drilling core placed on plastic foil.

Fig. 4. The character of the bentonite material; The Spanish Lookout deposit.

Fig. 5. Pure bentonite clay from the Spanish Lookout deposit.

Fig. 6. Cat litter prepared from bentonite from the Spanish Lookout deposit.

Ceramic clays

There are known occurrences of ceramic clays in the Swasey Bladen Forest Reserve in the southern part of Belize, at the northern edge of the Toledo District. This is a lowland area (15–35 m asl), located between the Bladen (Monkey River) waterway to the west and the Swasey Branch to the east. The area has very good access by the Southern Highway.

The final report of Tvrdý (2008) summarises the results of the prospecting works carried out by shallow hand-drilling. The deposit bodies can be defined as sub-horizontally deposited clay layers in a clayey-sandy formation. The maximum layer thickness encountered is 6.4 metres; the total depth range has not been verified. The geological age of the sediments is unclear, but rather than quaternary they are most probably of the Tertiary (or in some cases Late Cretaceous) age, i.e. they belong to the Toledo Formation. It is possible to search for the origin of the resource material in the denuded granite massifs that were intensively kaolinised at the end of the Cretaceous Period.

At the deposit, there is the occurrence of white-burning ceramic clays, suitable material for tiles and clays forming coloured ware that are suitable for the manufacture of stoneware items.

At the deposit, there is an estimated total 16.6 million tons of probable reserves of ceramic clays, especially suitable for the manufacture of stoneware items and of course elsewhere (for construction, sewage, chemical production, etc.). There are also white-burning clays applicable for use as tile materials. Due to the variability of the raw materials, the most advantageous usage appears to be the production of ceramic mosaics or the manufacture of construction ceramics with visible parts of a rustic character (e.g. analogous to the production of the Gres de Breda company, www.gresdebreda.com), for which it is advantageous to combine the entire range of quality levels represented on the deposit.

The entire area of the Swasey Bladen Forest Reserve, extending to circa 60 km^2, can still be considered as a prognostic area with the occurrence of raw materials of a similar quality.

Tab. 3. Chemical analysis of selected samples of ceramic clay from Swasey Bladen [wt. %].

Appearance after firing				
SiO_2	79.52	55.57	62.03	56.14
TiO_2	0.02	0.02	0.90	0.92
Al_2O_3	13.70	30.68	22.57	21.30
Fe_2O_3	0.78	1.37	4.03	9.26
CaO	<0.10	<0.10	<0.10	0.42
MgO	0.11	0.23	0.32	1.06
Na_2O	<0.10	0.21	0.10	<0.10
K_2O	1.01	2.63	1.82	0.66
L.O.I.	3.85	8.50	7.33	9.23

Feldspar raw material

After the verification of the deposit of clays at the Sweasey Bladen site, occurrences of feldspar raw materials were indicatively verified with the main purpose of supplementing the raw material for ceramic production. Most promising of the sites selected by the Belizean colleagues appeared to be a granite massif in the mountainous area of Pine Ridge (Souviron, 1991). Laboratory tests showed that from the coarse-grained pink granite from the Oakburn Line-Pinol Creek site, after grinding and electromagnetic separation, it is possible to obtain a product with a content of Fe_2O_3 of below 0.60 % and a proportion of feldspar of at least 40-50 %. The mining waste from the quarry for the decorative stone of the Caribbean Investors Ltd company could be a suitable raw material.

Also, the occurrences of granite eluvia are similar in nature, with the added advantage of there being no need for the disintegration of the rock by blasting and its subsequent crushing. Applicable in accordance with the requirement for its utilisation is its treatment by floating (i.e. for removal of the clayey content) and its magnetic separation (reduction of the Fe_2O_3 content). For the production of architectural elements with natural surfaces (façade tiles, greige tiles, etc.) it would probably also be possible to use ground granite eluvium without the need for the removal of the clayey content by floating.

Fig. 7. Exploratory drilling at the Swasey Bladen ceramic clay deposit using a hand-held Eijkelkamp auger set

Fig. 8. Swasey Bladen – a drilling core placed on plastic foil.

Tab. 4. Appearance of fired samples of granite eluvium from the Rio On site after their treatment by sieving and electromagnetic separation.

Fraction (mm)	0.1-0.315	0.315-0.63	0.63-1.0	1.0-2.0	2.0-5.0
Percentage share	14.5 %	18.7 %	16.4 %	23.1 %	24.7 %
Original samples	 K_2O **8,21** % Na_2O **0,76** % Fe_2O_3 **3,15** % Ti_2O **0,26** %	 K_2O **8,01** % Na_2O **0,70** % Fe_2O_3 **2,65** % Ti_2O **0,21** %	 K_2O **8,59** % Na_2O **0,58** % Fe_2O_3 **1,05** % Ti_2O **0,09** %	 K_2O **6,75** % Na_2O **0,51** % Fe_2O_3 **0,55** % Ti_2O **0,06** %	 K_2O **5,11** % Na_2O **0,47** % Fe_2O_3 **0,55** % Ti_2O **0,06** %
Samples following treatment by electromagnetic separation	 K_2O **7,50** % Na_2O **0,98** % Fe_2O_3 **0,89** % Ti_2O **0,09** %	 K_2O **8,19** % Na_2O **0,57** % Fe_2O_3 **0,49** % Ti_2O **0,06** %	 K_2O **7,74** % Na_2O **0,47** % Fe_2O_3 **0,44** % Ti_2O **0,05** %	 K_2O **6,53** % Na_2O **0,51** % Fe_2O_3 **0,48** % Ti_2O **0,05** %	 K_2O **5,52** % Na_2O **0,47** % Fe_2O_3 **0,23** % Ti_2O **0,03** %

Fig. 9. Rio On, Pine Ridge Mts.

Fig. 10. Sampling of granite grus in the Pine Ridge Mts.

Fig. 11. Granite quarry belonging to Caribbean Investors Ltd., in October 2009.

Dolomite deposits

In the year 2001, two dolomite deposits with total proven reserves of 400 million metric tons were discovered in the Stann Creek District in east-central Belize (Holland, 2003). The Soldier Creek deposit is located on the Coastal Road, approximately 27 km south of the junction with the Western Highway, formed by a range of hills that rise from the coastal plain savannah to a maximum elevation of 126 m asl. The Manatee Creek deposit is located approximately 7 km north of the Soldier Creek area and 6 km inland from the coast. It comprises three N-S trending elongated ridges and several small hills in the south. The maximum altitude is 102 m asl.

The dolomite deposits are described as the Late Cretaceous Barton Creek Formation. The deposits comprise a group of fault blocks that rise abruptly from the coastal plain that lies within the Northern Boundary Fault Zone. The faulting has created vertical fractures and brecciated zones. Some of the brecciated zones have been re-cemented by thin calcite veinlets. The karstification of the dolomite is not regarded as volumetrically significant (Holland, 2003).

The composition of the dolomite indicates its high degree of purity. According to Holland (2003), calcination of this material in a rotary kiln would produce extremely reactive lime with very low abrasion indices. Testing showed that the dolomite aggregate surpasses the Texas DOT standards for use in a hot mix asphaltic concrete. The deposits in the Stann Creek District add to the raw material base of the already mined Punta Gorda deposit in southern Belize.

Its possible fields of application include the following:

- the construction industry – as crushed and dimension stone;
- heavy industry – as a constituent in the production of steel in blast furnaces;
- the production of abrasives;
- the production of mineral wool;
- the glass industry;
- agriculture – for the stabilisation of acid soils and the production of agricultural lime; for the utilisation analogous to that of the Punta Gorda high-grade dolomite;
- the treatment of drinking water - granulated dolomite (as a silica-free filtration material), burnt dolomite, calcined dolomite (for de-acidification).

Tab. 5. Chemical composition of the dolomite from the Stann Creek District [wt. %].

	Mean and range of values, Soldier Creek deposit (Tvrdý 2010)	Typical analyses of the Manatee Creek and Soldier Creek deposits (Holland 2003)
SiO_2	0.19 0.09-0.27	0.08
Al_2O_3	0.06 0.03-0.09	<0.01
Fe_2O_3	0.06 0.05-0.08	0.02
TiO_2	0.01 -	-
CaO	32.5 30.99-33.86	30.5
MgO	20.0 18.80-21.40	20.4
K_2O	0.02 0.01-0.02	-
Na_2O	0.03 0.02-0.04	-
L.O.I.	47.08 46.96-47.25	47.3

Fig. 12. The landscape looking south from the George Price Highway; the Soldier Creek locality is on the horizon.

Fig. 13. Carrying-out geological documentation at the Soldier Creek site.

Fig. 14. Dolomite outcrop, Soldier Creek.

Fig. 15. Dolomite, Soldier Creek.

Fig. 16. Brecciated dolomite, Soldier Creek.

Discussion

As mentioned at the beginning of this paper, due to the very low costs in the production of this type of the raw materials - the competition in the global market has significantly increased during the recent years. Therefore companies are moving their interest into developing Central American countries such as Belize. As the result of our cooperation project, we have verified several economically interesting sources such as bentonite, ceramic clays, and feldspar and carbonate materials.

This development cooperation project was registered under the following title: "Mining and processing of industrial minerals in Jamaica and selected countries of CARICOM". Company GET Prague implemented it on behalf of the Czech government during the period 2006-2011 with the cooperation of the Geology and Petroleum Department of Ministry of Natural Resources and the Environment in Belize. Leading laboratories and institutions of the Czech Republic also contributed significantly to this project. The works on site were carried out in cooperation with Belize Minerals Ltd., Punta Gorda and other private entities in Belize.

Conclusion

Belizean geological surface consists of varieties of limestone, with the exception of Maya Mountains. A Large part of Belize lies outside the tectonically active zone opposite to the rest of Central America. A number of economically important minerals exist in Belize, such as bauxite, dolomite and barite, but none has been found in quantities which are large enough to secure their mining yet.

Three regions of Belize were assessed by our team and this project verified following raw material´s deposits – bentonite clays, ceramic clays, and feldspar and dolomite deposits.

Bentonite clays were assessed in the Cayo District of Western Belize. Based on the results of shallow boreholes drilling with usage of the hand-held auger set we assessed reserves of overall 649 thousand tonnes of bentonite clay in the Spanish Lookout deposit

There were known occurrences of ceramic clays in the Swasey Bladen Forest Reserve in the southern part of the country. At this deposit, there is an estimated total 16.6 million tons of probable reserves of ceramic clays, which are suitable for the manufacture of stoneware items or construction, sewage and chemical production. Additionally, we have verified deposits of clays at the Sweasey Bladen site. Occurrences of feldspar raw materials were indicatively verified with the main purpose of supplementing the raw material for ceramic production.

Lastly, two dolomite deposits with total proven reserves of 400 million metric tons were confirmed in the Stann Creek District in east-central Belize. The composition of the dolomite indicates its high degree of purity, and it can be used in various industries.

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