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Geochemical and mineralogical characterization of igneous rocks in Gharyan area (northwestern Libya) for potential industrial valorization

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Abstract

Igneous rocks are economically important with wide variety of uses. They were widely used by ancient civilizations and gained more applications today. They are mainly used in construction and ceramic industries, as sources of ore and minerals, and as several compounds associated to various chemical and technological applications. The wide outcrops of several igneous bodies in the Gharyan volcanic province according numerous forms and eruptive styles, gives the opportunity to endeavor geochemical and mineralogical characterization of varied samples with diverse mineralogies. This characterization involving chemical and DRX analyzes and thin section observation is mandatory to evaluate and classify these rocks and to decide if some of them can be subject for potential industrial uses. This is a key objective that will contribute

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to the Libyan industrial development and promote the usage of local geological resources.

Keywords: igneous rocks, geochemistry, mineralogy, industrial valorization, Gharyan volcanic province

التّوصيف الجيوكيميائي والمعدني للصخور النارية في منطقة غريان (شمال–غرب ليبيا) لغرض التثمين الصناعي

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الملخص

تحظى الصخور النارية بأهمية اقتصادية كبرى من خلال استخدامها في مجالات صناعيّة عديدة. حيث تم استخدامها منذ الحضارات القديمة وما انفكت تستخدم اليوم كمواد تدخل في صناعات مواد البناء والسيراميك، كمصدر للخامات والمعادن، وكمركبات عديدة تدخل في صناعات كيميائيّة وتكنولوجيّة مختلفة. ويعدّ ظهور العديد من الأجسام الصخريّة النارية في منطقة غريان وفق أشكال وأنماط بركانيّة متعددة فرصة للحصول على عيّنات متنوعة ذات تركيبات معدنيّة مختلفة تمكّن من تنفيذ توصيف جيوكيميائي ومعدني مفصّل لها. هذا التوصيف الذي يتضمن نتائج حيود الأشعة السينية، التّحاليل

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الكيميائيّة ومعاينة الشّرائح الرّقيقة للعيّنات يعتبر ضروريّا لتصنيف وتقييم هذه الصخور وتحديد احتمال استخدامها في مجال صناعي معيّن. ونتيجة هذا التّوصيف هو هدف رئيسي سيساهم في تنمية الصّناعة في ليبيا وتعزيز استخدام الموارد الجيولوجيّة المحليّة. لقد أظهرت النتائج الأوّليّة لهذا العمل أن البازلت والتراكيت والفونوليت هي أنواع الصّخور النّارية الأكثر شيوعًا في منطقة غريان، وقد تبيّن أنّ عيّنات التراكيت والفونوليت غير مشبعة بالسيليكا وتحتوي على نفلين معياري بنسب مئوية تتراوح من 3.2 إلى 22.6 وقلويات إجمالية عالية نسبيًا. كما تبيّن أنّ عيّنات البازلت مشبعة جزئيًا، وهي غنية نسبيًا بأكاسيد الحديد والمغنيسيوم مقارنة بعيّنات التراكيت والفونوليت. هذا وتختلف عيّنات التراكيت والفونوليت فيما بينها من حيث محتواها من القلويّات الاجماليّة والسيليكا. ولقد كان تواجد Na_2O بنسبة أعلى من K_2O في معظم عيّنات التراكيت والفونوليت سببا في ظهور معادن صوديوم مميزة مثل النفلين، الصودلايت، الكلينوبيروكسين الغني بالصّوديوم والأمفيبول القلوي.

الكلمات الافتتاحية: صخور النارية، جيوكيمياء، معادن، تثمين صناعي، إقليم غريان البركاني

Introduction

The Tertiary-Recent volcanic events in northwestern Libya were extensively developed between Gharyan and Tripoli and led to the establishment of several volcanic features in Gharyan volcanic province made of extrusive phonolitic rocks (Fig. 1). Previous studies attribute these rocks to four main groups based on their petrology, eruptive style and spatial distribution: the flood basalts, the phonolite domes, the late volcanic centres and the volcaniclastic rocks. The flood basalts are the most voluminous and represent over 90% by volume of the igneous activity of the volcanic eruptions. They have been divided into two main groups remarkably homogeneous in composition but related to two igneous activities (Busrewil and Wadsworth, 1996); the old lava series forming a

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laterally extensive lava plateau of about 3000 km^2 southeastern Gharyan city, and the young lava series resulted from tardive revivals of lava flows. The phonolites and trachytes outcrop in few localities as individual domal-shaped intrusions through the sedimentary cover with smooth circular to short oval contours. Rare phonolitic bodies are elongated which suggest the magma intrusion through structural discontinuities (Piccoli, 1970; Almond et al., 1974; Busrewil and Wadsworth, 1996).

The late volcanic centres represent minor volcanic vents and associated intrusions and can lie over the lava plateau. They form isolated distinct dark hills or cluster of hills rising above the lava plateau and the Mesozoic sequence (Busrewil and Wadsworth, 1980). The volcaniclastic rocks are mainly made of black fragmentary products of explosive eruptions (Piccoli, 1970; Gray,1971; Almond et al., 1974). These volcaniclasts are locally intruded by basanitic dykes (e.g. Kabdet Al Jamal, southwest of Kaf Tekut). According to Busrewil and Wadsworth (1996) the internal structure of these volcaniclastic material don't suggests that they have been transported and indicates that they have been formed initially by vent opening during phreatomagmatic explosions. Relatively tardive dykes appear as vertical to near vertical resistant walls in the area. Scattered occurrences of necks or feeders of mafic dykes and pyroclastic deposits with occasional presence of mantle-derived lherzolitic nodules are associated to vent of explosive eruption that rapidly transported a mixture of magma and accidentally caught xenoliths of peridotite in the rising magma from a great depth (Busrewil and Wadsworth, 1996).

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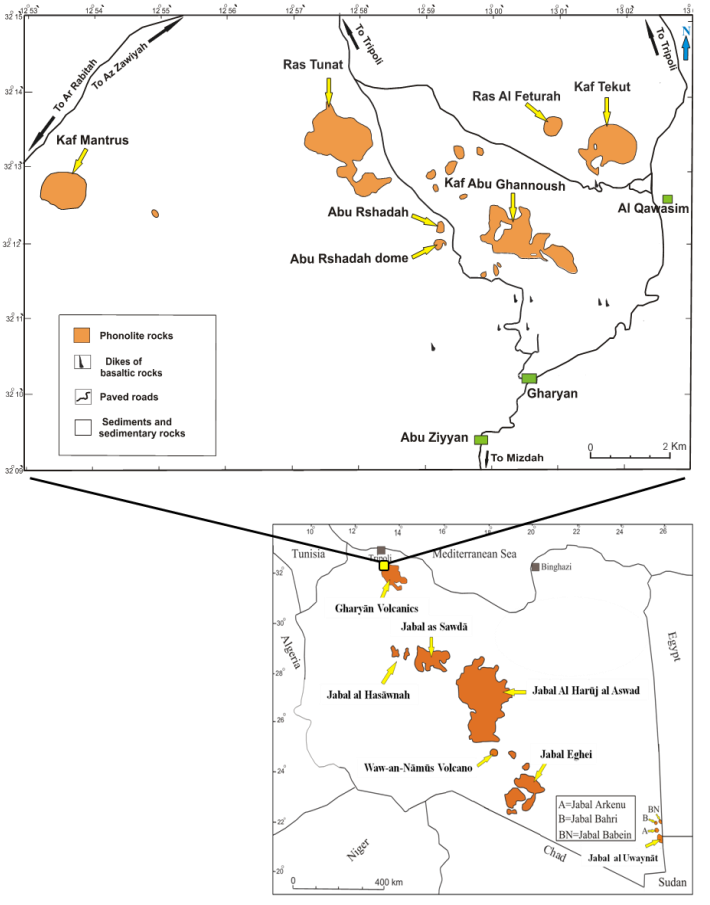

Fig. 1: Major Tertiary-recent magmatic rocks of Libya (modified after Goudarzi, 1970).

Data and Methodology

Forty samples of igneous rocks sampled from the Gharyan volcanic province have been gathered and located using GPS. These samples were subject of XRF and XRD analysis to determine their elementary chemical composition and crystalline structure. Some thin sections were also performed for some specific samples in goal to study their petrology and to reveal the origin and evolution of the rock.

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The samples were classified based on the chemical results. And some samples will be selected for industrial essays depending on the expected industrial usage of the material.

Preliminary results and expected essays

The results of chemical analysis of 25 samples are presented in Table 1. These results were analyzed using TAS diagram (Total Alkali -vs Silica) in goal to show the composition and assign names/class to the studied igneous rocks samples (Le Bas *et al.*, 1989). The established TAS diagram (Fig. 2) permitted to identify three main rock types: Basalts, Trachyte and Phonolites. Trachytes and phonolites are silica-undersaturated with a normative nepheline between 3.2 to 22.6 wt %, whereas the basalts are sub-saturated. The trachytes and phonolites differ chemically from the basalts by greater richness in total alkalis, whereas the basalts are richness in iron and magnesium oxides compared with the trachytes and phonolites. The trachytes are distinguished from the phonolites relatively by less contents of total alkalis (Max:13.14 wt%) and by more contents of silica (Min: 61.04 wt%). Most of trachytic and phonolitic analyzed samples have more Na_2O than K_2O which resulted in the appearance of distinctive sodic minerals such as nepheline, sodalite, sodium-rich clinopyroxene and alkali amphibole.

Trachytes are clear, rough igneous rocks used as ornamental and building stone and also in mosaics design and flooring since the prehistoric age (Pereira and Baltuille, 2014). Phonolites are fine-grained felsic igneous rocks lacking quartz, with felsics comprising 10-60% foids and alkali feldspar/total feldspar >0.9. Phonolites are used as a raw material in various fields of industry, as a dimension stone, aggregate for gravels, ceramics, and glass production and also in agriculture (Hidalgo-Herrador, 2021). Basalt rocks are the most common volcanic rock type (up over 90%). Basalt is a dark-colored, fine-grained, igneous rock composed mainly of plagioclase and pyroxene minerals. It is a hard, dense, safe (non-carcinogenic), durable rock with excellent engineering properties. This popular rock is used for aggregates, road bases, stone architecture,

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foundations, industry of basalt fibers, cast basalt, fertilizers and more (Chowdhury et al. 2022).

Table 1. Major and CIPW data for the studied samples of Gharyan igneous rocks.

Sample No		TRACHYTES			PHONOLITES																	BASALES				
		T15	T16	T24	2Ph	Ph6	Ph7	Ph10	Ph12	Ph13	Ph17	Ph18	Ph21	Ph22	Ph25	Ph26	Ph28	Ph29	Ph37	Ph42	Ph44	B31	B34	B35	B36	B45
M-EL	SiO2	61.15	62.04	61.89	57.66	60.84	60.12	59.36	57.78	57.13	58.75	59.54	58.89	58.87	61.16	59.01	60.06	61.01	60.84	59.87	60.36	52.16	48.46	54.36	49.13	51.88
	AL2O3	19.26	18.89	18.56	20.24	18.56	17.64	19.87	18.89	20.26	20.78	19.79	19.75	18.76	20.46	19.58	18.58	19.26	17.85	19.85	19.36	17.45	19.23	18.45	19.26	19.84
	Fe2O3t	2.34	2.82	2.84	2.52	2.33	1.94	1.97	2.80	2.24	2.53	2.48	2.52	2.48	1.06	2.77	2.64	1.78	2.20	1.69	1.58	10.26	11.87	11.01	9.14	11.31
	Na2O	6.84	6.96	7.47	7.02	8.96	9.08	8.87	9.36	9.24	9.49	9.19	8.55	9.59	7.63	9.50	7.68	8.67	9.38	6.02	8.82	2.39	3.50	2.51	1.85	2.43
	K2O	5.88	5.67	5.67	6.36	6.34	6.40	6.18	5.90	6.02	5.55	5.78	5.91	6.04	6.23	5.14	5.98	6.18	5.84	6.28	6.14	2.35	1.72	2.48	1.36	2.55
	MgO	0.24	0.21	0.08	0.18	0.05	0.07	0.05	0.08	0.09	0.11	0.03	0.04	0.14	0.10	0.12	0.08	0.05	0.04	0.08	0.05	11.49	11.66	7.72	11.95	7.83
	CaO	1.00	1.04	1.01	1.00	1.01	0.98	1.01	1.10	1.00	1.01	0.80	1.02	1.01	1.00	0.77	1.01	1.02	1.01	1.01	1.01	1.10	1.00	1.00	1.02	1.03
	MnO	0.13	0.20	0.19	0.13	0.13	0.14	0.14	0.21	0.22	0.18	0.23	0.20	0.20	0.12	0.23	0.19	0.17	0.20	0.13	0.17	0.14	0.15	0.16	0.15	0.14
	LOI	1.69	1.60	0.38	2.90	1.52	1.88	0.95	1.88	1.83	1.02	1.40	1.32	1.14	0.41	1.10	1.80	0.59	0.84	0.36	1.36	1.21	0.78	1.22	4.94	1.16
	Total	98.52	99.43	98.09	98.00	99.75	98.24	98.41	98.03	99.42	99.24	98.20	98.12	98.17	98.22	98.02	98.72	98.21	98.28	98.21	98.85	98.55	98.37	98.91	98.80	98.17
CIPW (wt %)	An	4.6	3.6	0.37	5.2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.25	0.00	0.00	0.00	0.00	0.00	0.00	5.60	5.10	5.10	5.40	5.30
	Ne	4.8	3.2	6.23	0.00	12.2	9.90	18.2	18.8	23.4	22.6	17.9	17.8	16.2	10.8	18.0	9.5	13.6	9.80	17.5	14.8	0.00	0.00	0.00	0.00	0.00
	Di	0.4	1.4	3.0	2.8	3.4	2.3	2.8	4.9	3.7	4.2	3.6	3.6	4.03	0.55	3.4	3.7	1.7	3.8	1.5	1.14	0.00	0.00	0.00	0.00	0.00
	Or	35.9	34.3	34.3	39.5	38.2	39.2	37.5	42.0	37.0	33.3	34.9	36.4	36.8	37.6	31.3	36.4	37.2	35.8	37.9	37.2	14.4	16.5	15.15	8.6	15.7
	Ab	51.9	54.3	53.8	39.7	38.7	38.9	35.9	25.8	30.4	35.5	38.2	38.1	34.9	46.0	41.1	46.5	40.9	42.7	36.2	39.7	20.7	30.3	21.9	16.8	21.4
	Wo	0.00	0.00	0.55	0.00	0.53	0.99	1.10	0.00	0.39	0.12	0.00	0.50	0.26	0.46	0.00	0.39	1.30	0.65	1.40	1.60	0.00	0.00	0.00	0.00	0.00
	Ol	0.60	0.87	0.00	0.88	0.00	0.00	0.00	0.16	0.00	0.00	0.20	0.00	0.00	0.00	0.84	0.00	0.00	0.00	0.00	0.00	0.00	25.0	0.00	0.00	0.00
	Ac	0.00	0.00	0.00	0.00	4.42	4.50	4.45	4.47	4.51	3.86	4.44	0.00	0.00	0.00	4.47	2.45	4.42	4.46	4.43	4.45	0.00	0.00	0.00	0.00	0.00
	mt	2.24	2.27	2.22	0.00	2.28	0.00	0.00	0.00	0.00	0.00	0.00	0.57	0.00	0.40	0.00	1.00	0.00	0.00	0.00	0.00	2.25	2.22	2.24	2.35	2.29
	Q	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.76	0.00	10.23	8.43	7.47

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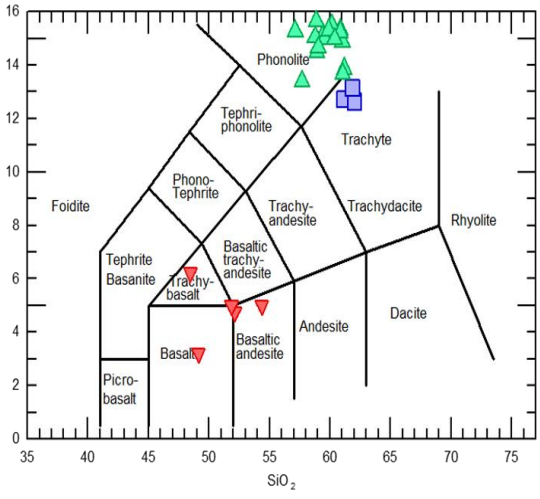

Fig. 2. Total alkalis vs. Silica (TAS) diagram performed for the studied samples.

We are working now with the "Building materials, Ceramic and Glass Technical Center" to perform some physicochemical characterization tests to select the best sample as raw material to be used in the potential industrial essays.

Conclusion and recommendation

Regarding all the above-mentioned potential usages of the igneous rocks class identified in the Gharyan volcanic province, especially for basalt which undergoes a flourishing global market valued at $310 million in 2022 (according to the Allied Market Research, Report A15885), the Libyan igneous rocks are considered valuable geological resources that can be developed and exploited in various industrial and technological usages. Such development is encouraged by the sustained availability of these resource in terms of quality and quantity and also the geotechnical conditions that seem mainly favorable for safe and economically benefitable industry.

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