



Production of Basaltic Cementitious Materials: Raw Material Assessment in Numerous Regions in Libya

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إنتاج المواد الأسمنتية البازلتية: تقييم المواد الخام في مناطق متعددة في ليبيا

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Abstract:

The primary objective of this study is to assess the viability of using Libyan basalt to produce high-quality basaltic cementitious materials, specifically basalt powder and fiber. The investigation focuses on basaltic rocks (including olivine basalt, alkali olivine basalt, and olivine tholeiite) sourced from seven key locations in Libya: Bani Walid, Qasr Ash Shwayrif, Jabal Al Hasawnah, Sabha, Al Fuqaha, Zallah, and Abu Naim. Methodology involved analyzing major oxide concentrations (SiO₂, Al₂O₃, Fe₂O₃, MgO, CaO, Na₂O, and K₂O) from 65 samples dated from the Eocene to Pleistocene. Results indicate that the chemical composition of the examined basalt is generally unsuitable for producing high-quality basalt powder or fiber. Specifically, major oxide levels often fall outside the required parameters for consistent melting and pozzolanic action, leading to subpar mechanical properties and instability in fibers. Despite these limitations, the basalt may be beneficial for other applications such as soil amendment. To enhance material quality for industrial use, the study recommends mixing the basalt with other materials to achieve ideal chemical ratios or employing acid leaching to adjust its composition for better processing.

Keywords: Cementitious Materials, Basalt Powder, Basalt Fiber, Libya.

المخلص

تتمثل الأهداف الرئيسية لهذه الدراسة في تقييم مدى جدوى استخدام البازلت الليبي لإنتاج مواد أسمنتية بازلتية عالية الجودة، وتحديدًا مسحوق وألياف البازلت. يركز البحث على الصخور البازلتية (بما في ذلك بازلت الأوليفين، وبازلت الأوليفين القلوي، والثوليت الأوليفيني) المستخرجة من سبعة مواقع رئيسية في ليبيا هي: بني وليد، وقصر الشويرف، وجبل الحساونة، وسبها، والفقهاء، وزلة، وأبو نجيم. اعتمدت

المنهجية على تحليل تركيزات الأكاسيد الرئيسية (مثل CaO ، MgO ، Fe_2O_3 ، Al_2O_3 ، SiO_2) عينة يعود تاريخها من العصر الإيوسيني إلى البليستوسين. وتشير النتائج إلى أن التركيب الكيميائي للبازلت المفحوص غير مناسب بشكل عام لإنتاج مسحوق أو ألياف بازلتية عالية الجودة. وبشكل أدق، فإن مستويات الأكاسيد الرئيسية غالباً ما تقع خارج المعايير المطلوبة لضمان الانصهار المتسق والنشاط البوزولاني، مما يؤدي إلى خصائص ميكانيكية ضعيفة وعدم استقرار في الألياف. وعلى الرغم من هذه القيود، قد يكون البازلت مفيداً في تطبيقات أخرى مثل تحسين التربة. ولتعزيز جودة المادة للاستخدام الصناعي، توصي الدراسة بخلط البازلت مع مواد أخرى للوصول إلى نسب كيميائية مثالية، أو استخدام الترشيح الحمضي لتعديل تركيبته من أجل معالجة أفضل.

الكلمات المفتاحية: المواد الأسمنتية، مسحوق البازلت، ألياف البازلت، ليبيا.

1. Introduction

Basalt is used in the cement industry as an economical and sustainable alternative to raw materials like clay or limestone, or as a powdered supplementary cementitious material that improves the strength, durability (acid/sulfate resistance), and workability of concrete while lowering transportation costs and CO_2 emissions. Basalt powder offers pozzolanic activity, improving mechanical properties (e.g., Uncik and Kmecova, 2013; Dobiszewska and Beycioglu, 2017, 2020; Chindaprasirt *et al.*, 2025), and basalt fibers reinforce concrete, increasing crack resistance and overall performance, contributing to greener construction practices (e.g., Wei *et al.*, 2011; Lipatov *et al.*, 2015; Khan and Cao, 2019; Liu *et al.*, 2022; Geng *et al.*, 2025).

There are substantial Cenozoic basalts in Libya (e.g., Schult and Soffel, 1973; Zivanovic, 1977; Jurak, 1978; Seidl and Rohlich, 1984; Woller, 1984; Gundobin and Yevdokimov, 1985; Vesely, 1985; Zikmund, 1985; Nemeth *et al.*, 2003; Farahat *et al.*, 2006; Cvetkovic *et al.*, 2010; Hamouda *et al.*, 2014; Alashkham *et al.*, 2024). Paleomagnetism (Schult and Soffel, 1973), petrogenesis (Cvetkovic *et al.*, 2010; Lustrino *et al.*, 2012), petrography and geochemistry (Farahat *et al.*, 2006; Abdel-Karim *et al.*, 2013; Alashkham *et al.*, 2024) have been the main topics of earlier research on Libyan basalt.

Evaluating the feasibility of producing basaltic cementitious materials (powder and fiber) from the Libyan basalt is the purpose of this research. The basalt was assessed in seven areas (Bani Walid, Qasr Ash Shwayrif, Jabal Al Hasawnah, Sabha, Al Fuqaha, Zallah, and Abu Naim, Fig. 1). The basalt age ranges from Eocene to Pleistocene (Zivanovic, 1977; Jurak, 1978; Seidl and Rohlich, 1984; Woller, 1984; Gundobin and Yevdokimov, 1985; Vesely, 1985; Zikmund, 1985).

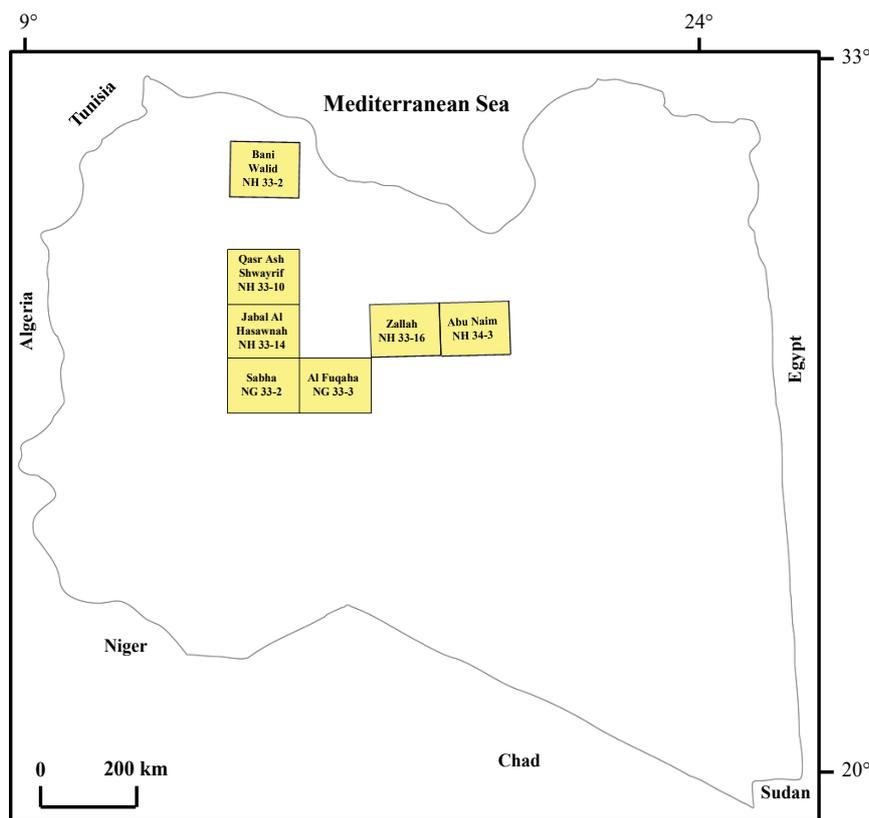


Fig. 1: Location map of the studied basalt.

2. Methodology

The chemical analysis data of basalt (65 samples) found in Zivanovic (1977), Jurak (1978), Seidl and Rohlich (1984), Woller (1984), Gundobin and Yevdokimov (1985), Vesely (1985), and Zikmund (1985) were used in this study. The major oxide (SiO_2 , TiO_2 , Al_2O_3 , Fe_2O_3 , FeO , MnO , MgO , CaO , Na_2O , K_2O , SO_3 , P_2O_5 , and Cl) concentration was the main focus of the investigation.

3. Results and Discussion

The studied basalt is divided into three types: (1) Olivine basalt (OB); (2) Alkali olivine basalt (AOB); and (3) Olivine tholeiite (OT) (Table 1). The chemical analysis data shows that SiO_2 , TiO_2 , Al_2O_3 , MnO , and Na_2O exhibit a slight difference in concentration (43.09-49.36%, 1.56-3.25%, 11.10-17.7%, 0.11-0.2%, and 2.2-3.9%, respectively), while there is a clear variance in the concentration of Fe_2O_3 , FeO , MgO , CaO , K_2O , and P_2O_5 (1.47-9%, 3.23-10.6%, 3.82-12.35%, 0.6-12.05%, 0.44-1.66%, and 0.16-1%, respectively). The concentrations of Cl and SO_3 were not determined in many samples.

The major components of basalt powder are SiO_2 , Al_2O_3 , Fe_2O_3 , MgO , CaO , Na_2O , and K_2O , while MnO , P_2O_5 , SO_3 , and Cl are the minor components (Table 2). The major oxide concentrations in the majority of the basalt samples are either much greater or lower than the typical chemical composition of basalt powder (Table 1 and Fig. 2). Overall, this indicates that the studied basalt is inappropriate for producing high-quality basalt powder, resulting in substandard performance, inconsistent fusion, or poor pozzolanic activity. However, other applications, including soil improvement, may benefit from the tested basalt.

The chemical composition of basalt fiber is shown in Table 3. The chemical composition of the studied samples and basalt fibers is obviously different, as Fig. 3 illustrates. The chemical composition of basalt fiber needs specific levels of SiO_2 for strength, Al_2O_3 for stability, and

controlled K_2O , Na_2O , MgO , CaO , TiO_2 to ensure good melting, formability, and resistance to alkaline environments. The unsuitable chemical composition of the studied basalt will lead to poor mechanical properties, instability, and property dispersion.

4. Conclusions and Recommendations

This study aimed to evaluate the possibility of manufacturing basaltic cementitious materials (powder and fiber) from the Libyan basalt. The basalt was studied in Bani Walid, Qasr Ash Shwayrif, Jabal Al Hasawnah, Sabha, Al Fuqaha, Zallah, and Abu Naim. Olivine basalt, alkali olivine basalt, and olivine tholeiite are the three kinds of the examined samples. The basalt has a chemistry that falls outside the narrow window required for producing high-quality, consistent basalt fiber or powder, necessitating adjustments or deeming it unsuitable. Soil amendment is one of the potential uses of the studied basalt. The following steps are recommended to improve the quality of the examined basalt: (1) Mixing with other types of basalt or materials to obtain the ideal chemical composition; and (2) Modifying the composition of the basalt, for example, through acid leaching, can adjust properties for better processing.

Table 1: Chemical analysis data (concentration in wt%) of basalt in the Bani Walid, Qasr Ash Shwayrif, Jabal Al Hasawnah, Sabha, Al Fuqaha, Zallah, and Abu Naim sheets (after Zivanovic, 1977; Jurak, 1978; Seidl and Rohlich, 1984; Woller, 1984; Gundobin and Yevdokimov, 1985; Vesely, 1985; Zikmund, 1985)

Sheet	Age	Rock type	Sample No. in the sheets	Sample No. in this work	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	MnO	MgO
Jabal Al Hasawnah	Tertiary	OB	34	S1	48.95	2.20	14.79	5.52	5.94	0.17	5.97
		OB	35	S2	47.84	1.97	13.54	5.67	5.84	0.16	7.97
		AOB	36	S3	45.50	2.48	13.43	5.73	6.62	0.17	9.25
		AOB	37	S4	46.16	3.10	14.98	4.48	7.50	0.19	6.42
		AOB	40	S5	43.09	2.81	11.52	5.69	6.93	0.17	12.35
		OB	43	S6	48.58	2.49	16.48	5.18	4.36	0.14	3.82
		AOB	44	S7	44.88	3.25	14.32	3.91	8.53	0.18	7.48
Al Fuqaha	Tertiary	AOB	7	S8	47.33	1.71	14.39	2.54	9.77	0.16	7.67
		AOB	8	S9	47.45	1.64	14.08	2.42	9.84	0.16	9.76
		AOB	9	S10	47.46	1.70	14.64	3.34	9.18	0.18	8.25
		AOB	10	S11	47.72	1.58	14.34	2.66	7.84	0.16	8.74
		AOB	11	S12	47.98	1.65	14.09	3.26	8.85	0.15	7.87
		OT	12	S13	48.25	1.56	14.45	2.98	8.73	0.14	8.33
		OB	13	S14	48.41	1.83	15.49	3.75	7.32	0.15	6.70
		AOB	14	S15	47.92	1.69	14.27	3.25	8.82	0.16	8.63
		OB	15	S16	48.03	1.56	15.25	1.96	9.61	0.18	8.19
		AOB	16	S17	48.22	1.70	13.75	1.63	10.06	0.17	9.23
		OB	17	S18	48.58	1.61	14.71	1.72	9.74	0.17	8.09
		OB	18	S19	48.67	1.67	14.33	1.85	9.85	0.16	8.42
		OT	19	S20	48.87	1.71	14.37	1.82	9.97	0.17	8.62
		OT	20	S21	48.97	1.70	14.26	1.47	10.28	0.16	8.58
OB	21	S22	49.29	1.73	14.00	1.77	9.78	0.16	10.10		
OT	22	S23	49.36	1.75	14.00	1.90	9.60	0.15	9.96		
Sabha	Tertiary	AOB	1	S24	46.37	2.62	11.27	2.31	10.13	0.16	10.48
		AOB	2	S25	46.20	2.38	11.10	1.91	10.60	0.17	11.37
		AOB	3	S26	45.64	2.24	12.38	3.10	9.79	0.19	9.02
		OT	4	S27	48.48	1.95	14.12	5.73	5.59	0.15	6.44
		OT	7	S28	46.04	2.26	13.26	3.06	9.45	0.16	8.87
		AOB	8	S29	45.48	2.56	14.74	4.82	7.00	0.20	6.81
		AOB	10	S30	46.52	1.88	14.04	4.04	7.46	0.16	6.42
		AOB	13	S31	47.54	1.84	14.10	5.00	6.53	0.16	6.63
		OB	14	S32	47.52	2.27	14.52	5.18	6.87	0.17	5.86
		AOB	15	S33	47.94	2.00	13.88	3.98	7.38	0.16	7.71
AOB	16	S34	44.89	2.50	12.94	7.94	4.98	0.18	9.55		
Bani Walid	Eocene-Pleistocene	OB	4	S35	45.20	2.10	17.70	4.70	9.30	0.15	6.20
Qasr Ash Shwayrif	Oligocene-Miocene	OB	1	S36	46.60	2.42	15.90	5.15	5.81	0.15	5.62
		OB	2	S37	47.45	2.42	14.90	7.27	4.13	0.15	6.32
		OB	3	S38	46.10	2.35	13.50	5.45	6.00	0.16	9.79
		OB	4	S39	46.00	2.27	13.70	7.05	4.91	0.17	7.68
		OB	5	S40	45.25	2.35	13.50	8.86	3.23	0.16	7.68
		OB	6	S41	48.43	2.24	13.69	9.00	3.75	0.14	6.37
		OB	7	S42	45.78	2.63	14.64	3.16	8.73	0.20	9.39
Zallah	Miocene	OT	1	S43	48.37	1.78	14.66	3.07	8.77	0.15	8.84
		AOB	2	S44	46.58	1.68	12.78	2.54	10.02	0.16	10.96
		OB	3	S45	48.77	1.66	15.60	2.08	9.00	0.13	7.77
		AOB	4	S46	47.05	1.74	14.56	2.91	8.19	0.14	8.00
		AOB	5	S47	46.57	2.95	12.61	2.67	9.48	0.16	8.27
		AOB	6	S48	46.91	1.95	13.32	2.20	10.09	0.17	9.61
		AOB	9	S49	48.20	2.11	15.54	3.34	6.57	0.13	5.68
		AOB	10	S50	46.75	1.90	13.81	2.18	9.76	0.16	8.76
		AOB	11	S51	48.37	2.12	14.00	3.61	7.85	0.14	8.06
		AOB	22	S52	47.30	2.45	12.73	2.89	8.37	0.15	8.34
		AOB	23	S53	46.97	1.82	14.04	2.98	9.20	0.15	10.00
		AOB	27	S54	47.37	1.76	14.47	3.48	8.32	0.15	8.52
		AOB	29	S55	46.50	1.73	12.62	2.46	10.60	0.16	11.73
		AOB	30	S56	47.70	1.84	14.09	2.11	9.55	0.14	9.14
		AOB	36	S57	46.96	1.79	13.69	2.21	9.59	0.15	9.81
		AOB	37	S58	47.49	1.71	15.04	1.92	7.36	0.12	6.87
AOB	38	S59	47.37	2.05	15.03	3.16	7.80	0.11	8.00		
Abu Naim	Miocene-Pleistocene	AOB	39	S60	47.14	1.78	14.37	2.66	9.23	0.15	8.52
		OB	41	S61	46.83	1.70	13.92	3.00	9.20	0.15	9.22
		AOB	42	S62	47.10	1.80	14.55	2.68	9.16	0.15	8.18
		AOB	44	S63	47.32	2.25	13.18	3.82	7.71	0.17	8.13
		AOB	45	S64	46.46	1.83	13.91	3.12	9.30	0.16	8.60
		OT	46	S65	47.49	1.75	14.29	2.91	9.27	0.17	9.15

Table 1: Continued

Sheet	Age	Rock type	Sample No. in the sheets	Sample No. in this work	CaO	Na ₂ O	K ₂ O	P ₂ O ₅	Cl	SO ₃
Jabal Al Hasawnah	Tertiary	OB	34	S1	10.30	2.61	0.98	0.35	0.04	0.04
		OB	35	S2	11.09	2.87	0.81	0.16	0.02	0.01
		AOB	36	S3	11.38	2.82	0.97	0.46	0.02	0.02
		AOB	37	S4	8.45	3.59	1.66	0.68	0.03	0.03
		AOB	40	S5	10.37	2.75	0.79	0.81	0.01	0.01
		OB	43	S6	8.51	3.88	1.66	0.63	0.02	0.01
		AOB	44	S7	9.46	3.05	1.39	0.72	0.02	0.03
Al Fuqaha	Tertiary	AOB	7	S8	10.16	3.00	0.44	0.20	<0.05	0.48
		AOB	8	S9	8.78	3.15	0.77	0.37	<0.05	0.30
		AOB	9	S10	9.42	3.20	0.47	0.20	<0.05	0.55
		AOB	10	S11	9.47	3.60	0.93	0.35	0.30	0.10
		AOB	11	S12	9.72	3.20	0.83	0.27	<0.05	0.52
		OT	12	S13	9.43	2.90	0.73	0.21	<0.05	0.28
		OB	13	S14	9.59	3.40	0.76	0.37	<0.05	0.23
		AOB	14	S15	9.26	3.20	0.75	0.26	<0.05	0.70
		OB	15	S16	9.16	3.20	0.70	0.26	<0.05	0.48
		AOB	16	S17	9.11	3.33	0.97	0.36	<0.05	0.35
		OB	17	S18	8.92	3.30	0.78	0.22	0.05	0.77
		OB	18	S19	8.98	3.30	0.75	0.24	<0.05	0.89
		OT	19	S20	8.61	3.10	0.77	0.25	<0.05	0.48
		OT	20	S21	8.61	3.20	0.76	0.25	<0.05	0.55
OB	21	S22	7.95	3.40	0.90	0.22	<0.05	0.09		
OT	22	S23	8.28	3.22	0.98	0.24	<0.05	0.05		
Sabha	Tertiary	AOB	1	S24	9.57	2.80	1.10	0.60	<0.05	0.09
		AOB	2	S25	9.17	2.90	1.22	0.54	<0.05	0.13
		AOB	3	S26	10.34	3.20	1.16	0.79	<0.05	0.10
		OT	4	S27	9.78	3.30	1.07	0.44	<0.05	0.10
		OT	7	S28	0.60	2.20	1.51	0.57	<0.05	0.10
		AOB	8	S29	8.79	3.50	1.45	0.70	<0.05	0.08
		AOB	10	S30	10.60	3.60	1.23	0.53	<0.05	0.15
		AOB	13	S31	10.97	3.20	0.99	0.47	<0.05	0.13
		OB	14	S32	10.45	3.20	1.17	0.59	<0.05	0.13
		AOB	15	S33	9.52	3.50	1.06	0.54	<0.05	0.03
AOB	16	S34	9.54	2.80	1.29	0.69	<0.05	0.04		
Bani Walid	Eocene-Pleistocene	OB	4	S35	9.90	2.90	0.75	0.45	-	-
Qasr Ash Shwayrif	Oligocene-Miocene	OB	1	S36	10.27	2.86	1.28	0.68	-	-
		OB	2	S37	10.28	3.29	1.33	0.69	-	-
		OB	3	S38	10.11	2.81	1.14	0.63	-	-
		OB	4	S39	11.03	3.00	1.24	0.60	-	-
		OB	5	S40	10.66	2.37	1.14	0.60	-	-
		OB	6	S41	12.05	2.62	1.09	0.63	-	-
		OB	7	S42	10.74	2.63	0.95	0.39	-	-
Zallah	Miocene	OT	1	S43	8.43	3.20	0.66	0.28	0.04	-
		AOB	2	S44	8.65	3.35	0.77	0.43	0.01	-
		OB	3	S45	8.68	3.55	0.66	0.21	0.02	-
		AOB	4	S46	10.47	3.30	0.77	0.31	0.05	-
		AOB	5	S47	10.11	2.95	1.15	0.62	0.01	-
		AOB	6	S48	8.49	3.70	0.87	0.48	0.03	-
		AOB	9	S49	10.49	3.50	1.47	0.58	0.03	-
		AOB	10	S50	9.50	3.50	0.85	0.52	0.05	-
		AOB	11	S51	8.66	3.60	1.36	1.00	0.03	-
		AOB	22	S52	10.19	3.23	1.26	0.64	0.03	-
		AOB	23	S53	8.51	3.32	0.74	0.34	0.05	-
		AOB	27	S54	8.98	3.40	0.82	0.48	0.19	-
		AOB	29	S55	8.12	3.10	0.56	0.24	0.02	-
		AOB	30	S56	9.33	3.46	0.69	0.29	0.04	-
AOB	36	S57	9.79	3.30	0.65	0.44	0.03	-		
AOB	37	S58	11.69	3.30	0.78	0.46	0.07	-		
AOB	38	S59	9.11	3.50	1.55	0.49	0.03	-		
Abu Naim	Miocene-Pleistocene	AOB	39	S60	10.28	3.50	0.63	0.36	0.04	-
		OB	41	S61	9.41	3.00	0.60	0.43	0.01	-
		AOB	42	S62	9.18	3.90	0.66	0.43	0.14	-
		AOB	44	S63	11.18	3.44	1.15	0.38	0.05	-
		AOB	45	S64	9.21	3.50	0.67	0.42	0.05	-
		OT	46	S65	8.94	3.00	0.63	0.45	0.03	-

Table 2: Chemical composition of basalt powder (after Dobiszewska and Beycioglu, 2020)

Oxides	Concentration (%)
SiO ₂	42.61
Al ₂ O ₃	12.9
Fe ₂ O ₃	14.05
MgO	7.82
CaO	13
Na ₂ O	1.76
K ₂ O	1.15
MnO	0.25
P ₂ O ₅	1.8
SO ₃	0.07
Cl	0.1

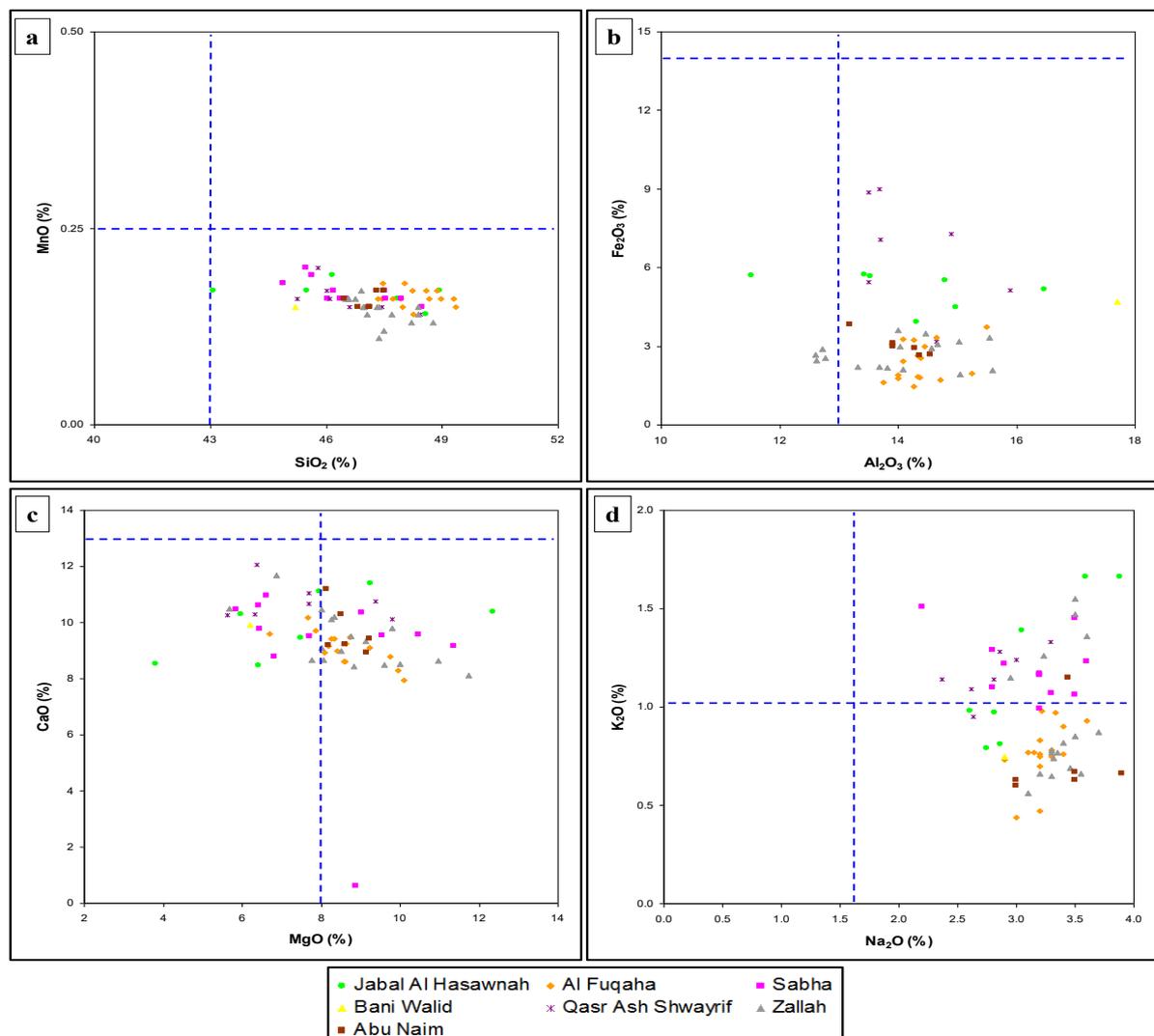


Fig. 2: Binary plots showing the unsuitability of the studied samples for producing high-quality basalt powder ((a) SiO₂ vs. MnO, (b) Al₂O₃ vs. Fe₂O₃, (c) CaO vs. MgO, and (d) Na₂O vs. K₂O)). The blue line indicates the standard chemical composition of basalt powder.

Table 3: Chemical composition of basalt fiber (after Liu *et al.*, 2022)

Oxides	Concentration (%)
SiO ₂	51.6–59.3
Al ₂ O ₃	14.6–18.3
CaO	5.9–9.4
MgO	3–5.3
Na ₂ O+K ₂ O	3.6–5.2
TiO ₂	0.8–2.25
Fe ₂ O ₃ +FeO	9–14
Others	0.09–0.13

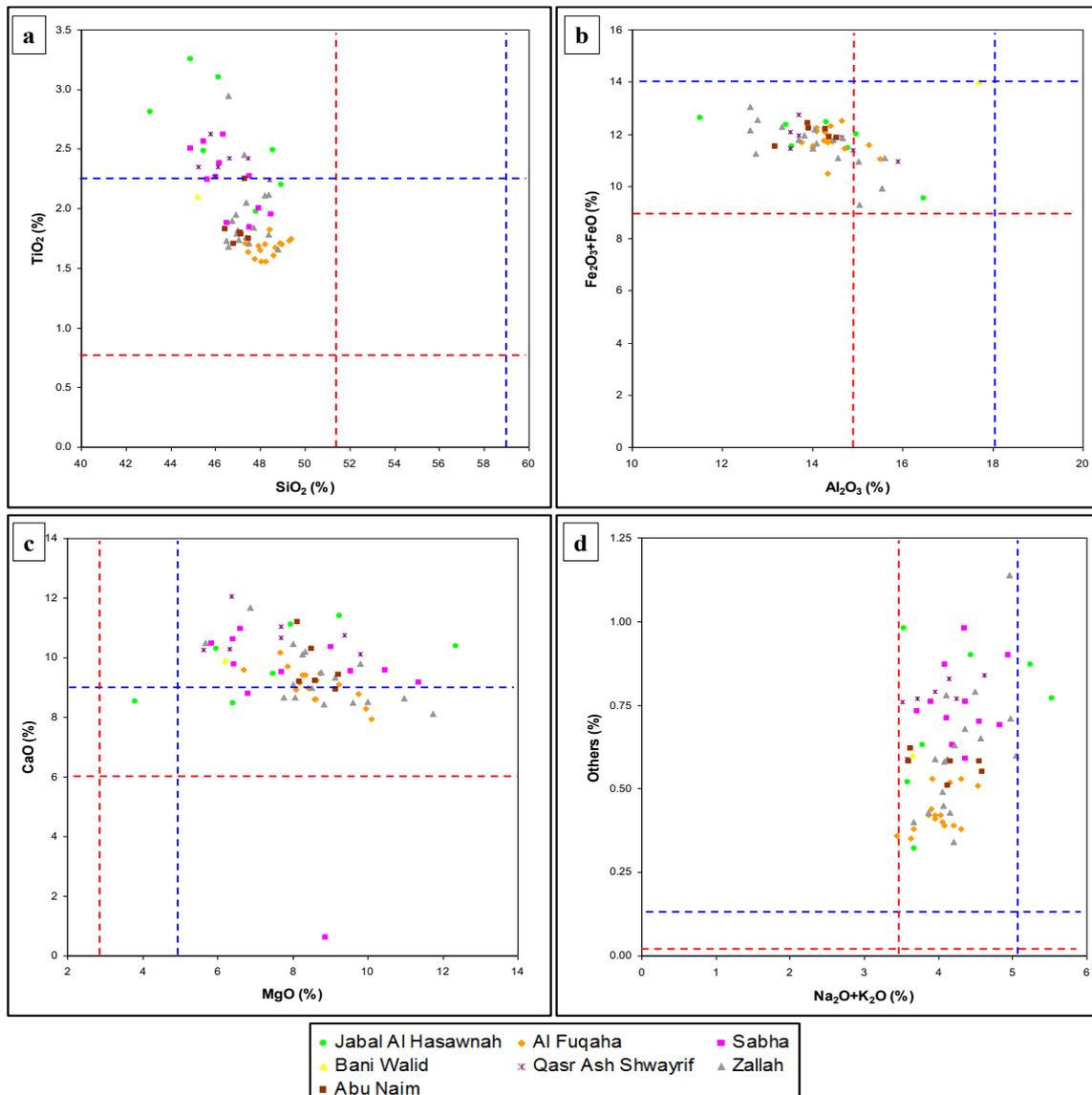


Fig. 3: Binary plots showing the unsuitability of the studied samples for producing high-quality basalt fiber ((a) SiO₂ vs. TiO₂, (b) Al₂O₃ vs. Fe₂O₃+FeO, (c) CaO vs. MgO, and (d) Na₂O+K₂O vs. MnO+P₂O₅). The red line indicates the lower limits of basalt fiber, whereas the blue line represents the higher limits.

Compliance with ethical standards

Disclosure of conflict of interest

The authors declare that they have no conflict of interest.

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