

# Organic Geochemical Analysis of Oil Inclusions in Quartz Collected from Afghanistan and Pakistan

Shigenori Ogihara

Faithful Crystals, Akihabara, Tokyo, Japan  
Email: faithful.love.crystals@gmail.com

**How to cite this paper:** Ogihara, S. (2025) Organic Geochemical Analysis of Oil Inclusions in Quartz Collected from Afghanistan and Pakistan. *American Journal of Analytical Chemistry*, 16, 280-289.  
<https://doi.org/10.4236/ajac.2025.1612018>

**Received:** November 2, 2025

**Accepted:** December 27, 2025

**Published:** December 30, 2025

Copyright © 2025 by author(s) and Scientific Research Publishing Inc. This work is licensed under the Creative Commons Attribution International License (CC BY 4.0).

<http://creativecommons.org/licenses/by/4.0/>



Open Access

## Abstract

This study conducted organic geochemical analyses of oil inclusions in quartz samples collected from Afghanistan and Pakistan. Samples from both countries contained large amounts of *n*-alkanes; however, sterane, triterpane, and isoprenoid hydrocarbons were not detected. Small amounts of *iso*- and *anteiso*-alkanes as well as alkylcyclohexanes were identified. The individual carbon isotope compositions of *n*-alkanes showed different trends between the two sample sets. The fluorescent compounds were separated into the polyaromatic hydrocarbon (PAH) fraction. Gas chromatography-mass spectrometry (GC-MS) analysis revealed that alkylbenzenes, particularly ethylbenzene, were the major components in the PAH fraction. The fluorescence observed in the oil-bearing quartz was attributed to the presence of alkylbenzenes.

## Keywords

Alkylbenzenes, Double-Terminated Quartz, Fluorescence, Oil Inclusion, Oil Quartz

## 1. Introduction

Double-terminated quartz crystals, such as Herkimer diamonds, reported from a wide range of sedimentary rocks, are characterized by the presence of organic matter as inclusions. In particular, the double-terminated crystals containing petroleum inclusions from Pakistan and Afghanistan are referred to as “oil quartz” because they contain petroleum-like substances that exhibit fluorescence when exposed to a Mineralight ultraviolet lamp. The fluorescence observed in inclusions within these specimens is of particular interest to novice mineral collectors. However, oil quartz occurring in the border areas between Pakistan and Afghanistan cannot be

analyzed due to geopolitical constraints. Consequently, the detailed occurrence of oil quartz in these regions remains unclear. In this study, fluorescence spectrometric analysis was conducted, oil was extracted, and GC-MS analysis was performed to identify the fluorescent compounds.

## 2. Samples and Analytical Procedure

The crystals used for the analyses included samples collected from 1) Chanman, Kandahar, Afghanistan, and 2) the Kharan District of Balochistan, Pakistan. These two sampling sites are located approximately 300 km apart, from north to south. The samples were purchased at the Tokyo Mineral Show. Due to geopolitical reasons, field surveys are difficult to carry out, and unfortunately, it is not possible to observe the occurrence of oil-bearing quartz *in situ*.

Oil-bearing quartz is a highly transparent, double-terminated crystal that contains both liquid oil and solid organic matter as inclusions. The external morphology of the oil quartz is characterized by rhombohedral faces (R and r) of different sizes. The *m* faces (prism faces) are observed as small facets, and the crystal is double-terminated with a microfacet *x*. Due to the presence of several microfacets, oil quartz exhibits more than 18 crystal faces (12 rhombohedral and 6 prism faces). Based on its external morphology, this quartz is not high quartz, although it possesses the same rhombohedral faces (**Figure 1**).



**Figure 1.** Double-terminated oil quartz from Pakistan. Natural light (left), fluorescence under 365nm ultraviolet light (right).

Oil quartz crystals were cleaned with dichloromethane/methanol (1:1, v/v). Each crystal was carefully crushed into small fragments using an agate mortar and pestle. The crushed crystals were rinsed with dichloromethane, and the solvent was recovered and concentrated by a nitrogen evaporation method. Organic matter was extracted from the oil inclusions within the quartz crystals.

Fluorescence spectroscopic analysis was first performed on the concentrated organic extract. The isolated samples were dissolved in hexane and analyzed using

an FP-8500 fluorometer (JASCO, Tokyo, Japan). Fluorescence spectra were recorded over an emission wavelength range of 265 - 750 nm at 1-nm intervals, with excitation wavelengths set at 254 and 365 nm. These excitation wavelengths correspond to the short- and long-wavelength ultraviolet light of a Mineralight UV lamp, which are commonly used by mineralogists.

In succession, the isolated organic matter was separated into four fractions by silica gel column chromatography. A hydrocarbon fraction (N-1) was eluted with two column volumes of *n*-hexane; an aliphatic hydrocarbon fraction (N-2) with two column volumes of *n*-hexane/dichloromethane (1:1, v/v); an aliphatic ketone and ester fraction (N-3) with seven column volumes of *n*-hexane/dichloromethane (1:1, v/v); and a polar fraction (N-4) with excess dichloromethane/methanol (1:1, v/v). Fractions N-1 and N-2 were analyzed by gas chromatography-mass spectrometry (GC-MS) and gas chromatography-combustion-isotope ratio mass spectrometry (GC-C-IRMS). Compounds were identified by comparison with published reference data. GC-MS analyses were performed using a ThermoQuest Voyager GC/MS system equipped with a 30 m fused-silica capillary column (HP-5ms; 0.25 mm i.d.; 0.25  $\mu$ m film thickness) and an on-column injector. The oven temperature was programmed as follows: isothermal at 40 °C for 1 min, ramped from 40 °C to 300 °C at 4 °C·min<sup>-1</sup>, and held isothermal at 300 °C for 25 min.

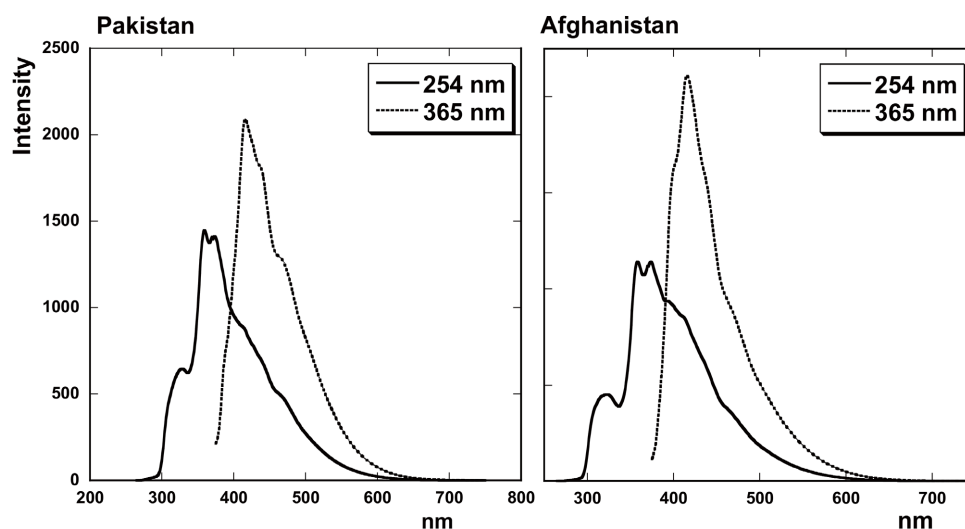
The GC-C-IRMS system consisted of an HP 6890 gas chromatograph equipped with a 30 m fused-silica capillary column (DB-5; 0.32 mm i.d.; 0.25  $\mu$ m film thickness; splitless injector), coupled via a Thermo Finnigan GC Combustion III interface to a Finnigan MAT Delta Plus isotope ratio mass spectrometer. The GC oven temperature was programmed as follows: isothermal at 60 °C for 1 min, ramped from 60 °C to 300 °C at 3 °C·min<sup>-1</sup>, and held isothermal at 300 °C for 25 min. Stable carbon isotope compositions were expressed as  $\delta^{13}\text{C}$  values relative to the V-PDB standard, with an analytical uncertainty of less than  $\pm 1.0\text{‰}$  based on repeated measurements of coinjected standards.

### 3. Result

**Figure 2** shows the fluorescence intensity spectra of oil quartz inclusions from samples collected in Pakistan and Afghanistan, excited at wavelengths of 254 and 365 nm. These two ultraviolet wavelengths are commonly used by mineralogists for mineral identification. The fluorescence intensity was higher under 365 nm excitation than under 254 nm excitation. Upon excitation at 365 nm, a bluish-purple fluorescence peak was observed at 417 nm. Even when using commercially available, cost-effective ultraviolet lamps (365 - 370 nm), blue-violet fluorescence was clearly visible. The yellowish portions observed are not fluorescence, but rather the inherent color of the oil inclusions themselves.

Ultraviolet irradiation was applied to the sample, which had been separated into four fractions by silica gel column chromatography. Only the PAH fraction (N-2) exhibited fluorescence, indicating that the fluorescence-emitting compounds were concentrated in this fraction. GC-MS analyses of all four fractions revealed that

several compounds were detected in the hydrocarbon (N-1) and PAH (N-2) fractions, whereas clear peaks were not observed in the ketone/ester (N-3) and polar (N-4) fractions. Therefore, only the hydrocarbon and PAH fractions are discussed in this study.



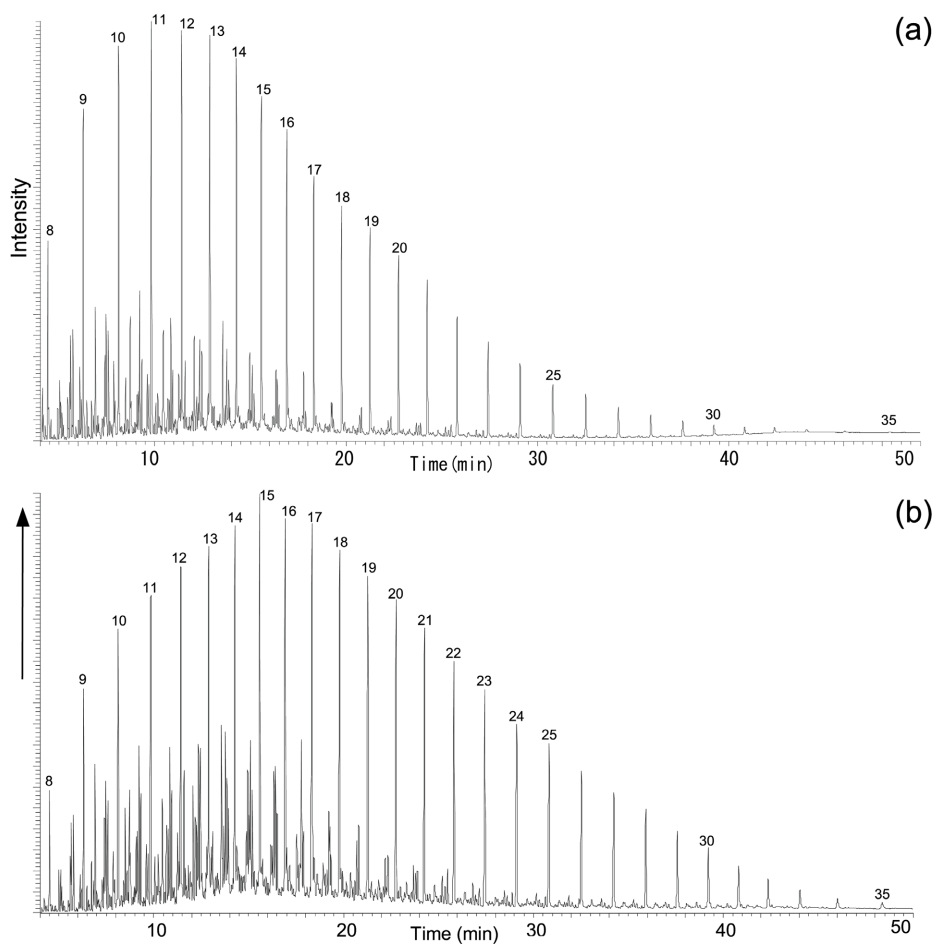
**Figure 2.** Fluorescence emission spectra of oil quartz samples collected from Afghanistan and Pakistan under excitation at 254 nm and 365 nm.

**Figure 3** shows the total ion chromatograms (TICs) of the hydrocarbon fractions of oil inclusions from oil quartz samples collected from (a) Afghanistan and (b) Pakistan.

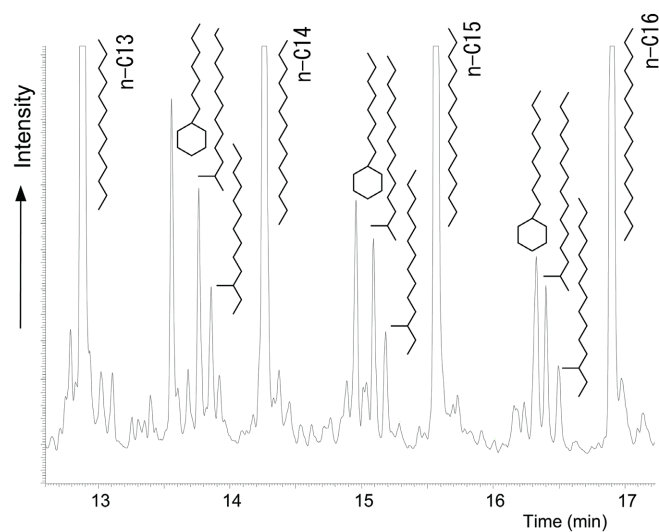
The samples are characterized by *n*-alkanes with a maximum at C<sub>11</sub>, and *n*-alkanes with carbon numbers up to C<sub>35</sub> were confirmed. No preference for even-carbon *n*-alkanes over odd-carbon *n*-alkanes was observed. Cyclic biomarkers such as triterpanes and steranes, as well as acyclic isoprenoid hydrocarbons such as pristane and phytane, were not detected.

The carbon preference index (CPI) of *n*-alkanes in both samples was 1.01. The CPI is an indicator of the thermal maturity of organic matter, and a value of 1.01 suggests that the samples fall within the oil-generation zone. The absence of biomarkers cannot be attributed to thermal maturation of the organic matter [1].

**Figure 4** presents an enlarged view of the TIC of the hydrocarbon fraction in the region between *n*-C<sub>13</sub> and *n*-C<sub>16</sub> alkanes. In **Figure 3(a)**, *iso*-alkanes (2-methylalkanes), *anteiso*-alkanes (3-methylalkanes), and alkylcyclohexanes were detected. Alkylcyclohexanes with both odd- and even-numbered carbon chains were observed. In terms of relative abundance, *n*-alkanes were the most abundant, followed by alkylcycloalkanes, *iso*-alkanes, and *anteiso*-alkanes, in that order. Unsaturated compounds were not detected. The decrease in the abundance of these compounds toward higher carbon numbers was more rapid than that of the *n*-alkanes, reaching the detection limit near C<sub>25</sub>.



**Figure 3.** Total ion chromatograms (TICs) of the hydrocarbon fraction of oil inclusions in quartz samples collected from (a) Afghanistan and (b) Pakistan. Numbers indicate the carbon number of *n*-alkanes.

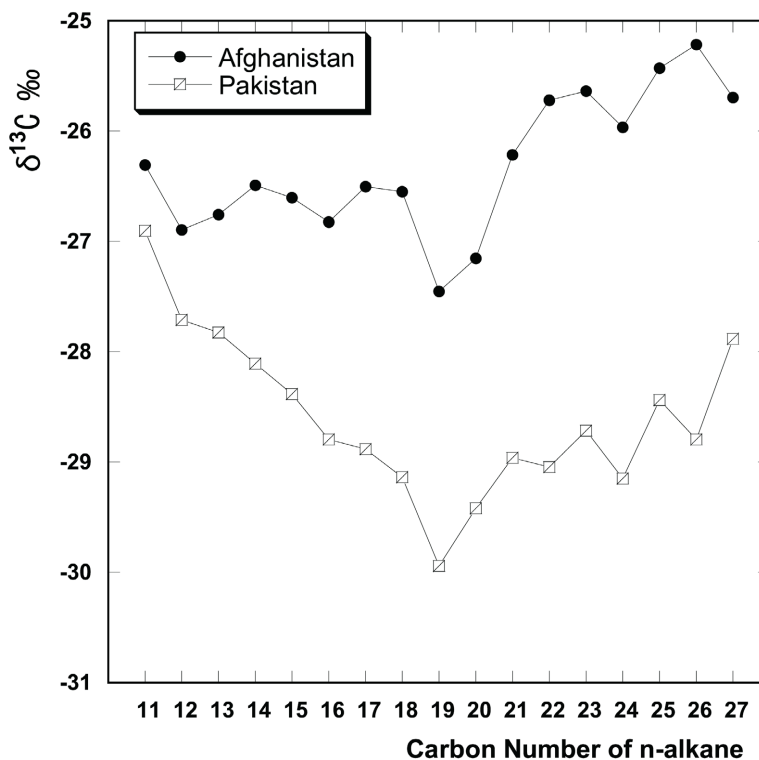


**Figure 4.** Magnified TIC of the hydrocarbon fraction of oil inclusions in the quartz sample collected from Afghanistan.

**Figure 3(b)** shows the TIC of the hydrocarbon fraction of oil inclusions in quartz samples collected from Pakistan. The *n*-alkanes exhibit a distribution with C<sub>15</sub> as the maximum. Cyclic biomarkers such as triterpanes and steranes, as well as acyclic isoprenoid hydrocarbons such as pristane and phytane, were not detected. The detected alkylcycloalkanes, including *iso*- and *anteiso*-alkanes, are highly similar to those observed in quartz samples from Afghanistan.

The absence of cyclic biomarkers, such as hopane and sterane from oil-bearing quartz, suggests that acyclic biomarkers were preferentially extracted when the hydrothermal fluids that precipitated the quartz extracted organic matter from the surrounding rocks.

**Figure 5** shows the individual carbon isotope compositions ( $\delta^{13}\text{C}$ ) of *n*-alkanes purified from oil inclusions in each quartz sample.  $\delta^{13}\text{C}$  values were obtained for *n*-alkanes ranging from C<sub>11</sub> to C<sub>27</sub>. In the samples from Pakistan, the  $\delta^{13}\text{C}$  value at C<sub>11</sub> is  $-27\text{‰}$ , decreases to  $-30\text{‰}$  at C<sub>19</sub>, and then increases to  $-28\text{‰}$  at C<sub>27</sub>. In contrast, the samples from Afghanistan exhibit a slight decrease from C<sub>12</sub>, followed by a minor increase up to C<sub>18</sub>. Although both sets of samples show a minimum at C<sub>19</sub> followed by an increase, the detailed pattern differs: the C<sub>19</sub> value in the Afghanistan samples is as high as  $-25.5\text{‰}$ , indicating a distinct carbon isotope trend compared with the Pakistan samples. The difference in *n*-alkane isotopic composition of oil-bearing quartz is due to differences in source rock composition resulting from differences in depositional environments. Detailed discussion requires observation and analysis of the host rock of oil-bearing quartz.



**Figure 5.** Distribution of  $\delta^{13}\text{C}$  values of *n*-alkanes as a function of carbon number.

Figure 6(a) shows the TIC of the PAH fraction of oil inclusions in quartz samples collected from Afghanistan. Table 1 summarizes the compound names, molecular weights, and characteristic ions corresponding to the numbered peaks. ♦ and ● indicate C-5 alkylbenzene and C-2 propenylbenzene, respectively.

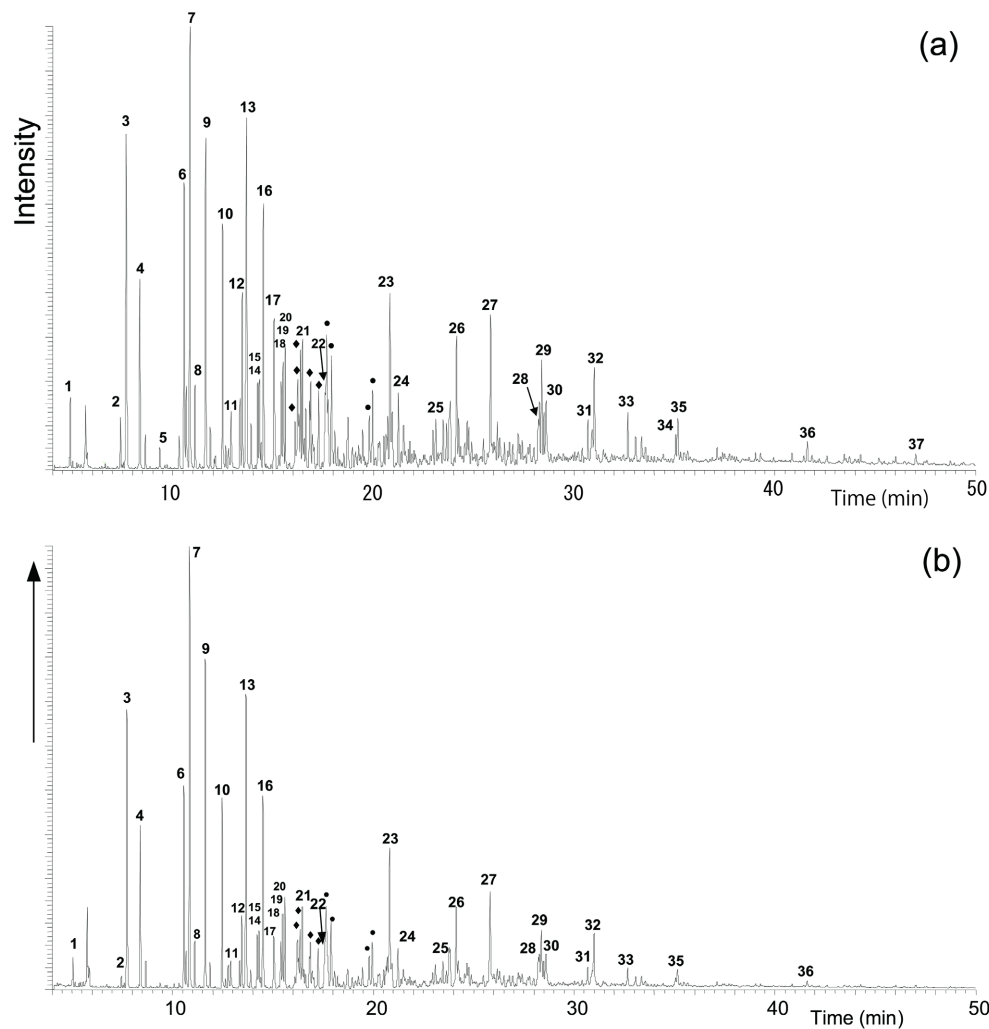


Figure 6. Total ion chromatograms (TICs) of the PAH fraction of oil inclusions in quartz samples collected from (a) Afghanistan and (b) Pakistan. Numbers correspond to the alkylbenzenes and PAHs listed in Table 1. ♦ and ● indicate C-5 alkylbenzene and C-2 propenylbenzene, respectively.

Table 1. Identifications of alkylbenzenes and PAHs in oil quartz.

Peak No.	Compound Name	MW	Characteristic Ions		
1	Toluene	92	91	92	
2	Ethylbenzene	106	91	105	106
3	1,3-Dimethylbenzene + 1,4-Dimethylbenzene	106	91	105	106
4	1,2-Dimethylbenzene	106	91	105	106
5	Isopropylbenzene (Cumene)	120	91	105	120
6	1-Methyl-3-ethylbenzene	120	91	105	120

## Continued

7	1,3,5-Trimethylbenzene	120	105	119	120
8	1-Methyl-2-ethylbenzene	120	91	105	120
9	1,2,4-Trimethylbenzene	120	105	119	120
10	1,2,3-Trimethylbenzene	120	105	119	120
11	Indane	118			
12	1,3-Diethylbenzene	134	105	119	134
13	1,3-Dimethyl-4-ethylbenzene	134	119	134	
14	1,2-Dimethyl-4-ethylbenzene	134	119	134	
15	1,3-Dimethyl-2-ethylbenzene	134	119	134	
16	1,2,4,5-Tetramethylbenzene	134	119	134	
17	1-Methyl-4- <i>tert</i> -butylbenzene	148			
18	<i>sec</i> -Pentylbenzene	148			
19	1,2,3,5-Tetramethylbenzene	134	119	134	
20	1,2,3,4-Tetramethylbenzene	134	119	134	
21	1-Methyl-4-propenylbenzene	132	117	132	
22	Naphthalene	128	128		
23	2-Methylnaphthalene	142	141	142	
24	1-Methylnaphthalene	142	142	141	
25	Acenaphthene	154			
26	Dimethylnaphthalene	156	156	141	115
27	Diphenylmethane	174	131	103	174
28	Fluorene	166	165	166	
29	Dimethylacenaphthene	182	182	167	165
30	Dimethylacenaphthene	182	182	167	165
31	C <sub>3</sub> -acenaphthene	196	196	181	
32	C <sub>2</sub> -acenaphthene	182	182	167	
	+ Methylfluorene	180	165		
33	Phenanthrene	178	178	176	
34	2-Methylphenanthrene	192	192	191	
35	1-Methylphenanthrene	192	192	191	
36	C <sub>2</sub> -cyclopentaphenanthrene	218	218	189	
37	Methylchrysene	242	242		
◆	C <sub>5</sub> -benzene	148	148		
●	C <sub>2</sub> -propenylbenzene	146	146	131	

Among these, compounds 2 - 4, 6 - 10, 12 - 15, 19, and 20 correspond to ethylbenzenes. In addition, relatively small amounts of naphthalene (22), acenaphthalene (25), fluorene (28), and their alkylated derivatives were detected (**Table 1**). The structural assignments of the alkylbenzenes were based on several previous studies [2]-[5].

**Figure 6(b)** shows the TIC of the PAH fraction of Pakistani oil inclusions in

the quartz sample. The numbered compounds correspond to the same compounds detected in the samples from Afghanistan. Overall, similar mass chromatograms were observed.

#### 4. Conclusions

In this study, oil inclusions in quartz samples collected from Afghanistan and Pakistan were excited with ultraviolet light at 365 nm, which resulted in blue-violet fluorescence at 417 nm. When the samples were separated into four fractions by silica gel column chromatography, only the PAH fraction exhibited fluorescence.

GC-MS analysis of the oil inclusions revealed that the hydrocarbon fraction was dominated by *n*-alkanes and lacked biomarkers such as triterpanes, steranes, and isoprenoid hydrocarbons. In addition, the hydrocarbon fraction contained relatively small amounts of *iso*- and *anteiso*-alkanes, as well as alkylcyclohexanes, with no preference for odd- or even-numbered carbon chains. Alkylcyclohexanes originating from contamination by plastics show homologs with exclusively odd- or even-numbered carbons (Ogihara, unpublished data); however, the alkylcyclohexanes detected in these samples were free from such contamination.

Distinct trends in the individual carbon isotope compositions of *n*-alkanes were observed between the samples collected from Afghanistan and Pakistan. Similar results were obtained from the analysis of the PAH fractions in both sets of samples, with alkylbenzenes—particularly ethylbenzenes—being predominant. The fluorescence observed under ultraviolet-light excitation likely originated from these alkylbenzenes.

The unique organic composition in quartz is thought to result from fractional extraction that occurred when the hydrothermal fluids responsible for precipitating the quartz passed through sedimentary rocks containing highly mature organic matter. Analyzing the sedimentary rocks that served as the source rocks is essential for investigating the origin of the oil in the quartz.

This study describes the source of the fluorescence in oil quartz samples from Afghanistan and Pakistan. Unfortunately, as the occurrence of oil quartz in these regions remains completely unknown, its origin cannot be discussed.

This is the limit of what can be obtained from samples purchased as mineral specimens. Furthermore, because the source area is located in a conflict zone, on-site investigation is not feasible.

Future research will aim to clarify the occurrence and origin of oil quartz based on the data reported herein.

#### Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

#### References

- [1] Heroux, Y., Chagnon, A. and Bertrand, R. (1979) Compilation and Correlation of Major Thermal Maturation Indicators. *AAPG Bulletin*, **63**, 2128-2144.

- 
- [2] Gerasimenko, V.A., Kirilenko, A.V. and Nabivach, V.M. (1981) Capillary Gas Chromatography of Aromatic Compounds Found in Coal Tar Fractions. *Journal of Chromatography A*, **208**, 9-16. [https://doi.org/10.1016/s0021-9673\(00\)87953-4](https://doi.org/10.1016/s0021-9673(00)87953-4)
- [3] Hartgers, W.A., Sinninghe Damsté, J.S. and de Leeuw, J.W. (1992) Identification of C<sub>2</sub> C<sub>4</sub> Alkylated Benzenes in Flash Pyrolysates of Kerogens, Coals and Asphaltenes. *Journal of Chromatography A*, **606**, 211-220. [https://doi.org/10.1016/0021-9673\(92\)87027-6](https://doi.org/10.1016/0021-9673(92)87027-6)
- [4] Mathiesen, M.D. and Lubeck, A.J. (1998) Improving Accuracy in the Determination of Aromatics in Gasoline by Gas Chromatography-Mass Spectrometry. *Journal of Chromatographic Science*, **36**, 449-456. <https://doi.org/10.1093/chromsci/36.9.449>
- [5] Yan, A. and Hu, Z. (2001) Linear and Non-Linear Modeling for the Investigation of Gas Chromatography Retention Indices of Alkylbenzenes on Cit.A-4, SE-30 and Carbowax 20M. *Analytica Chimica Acta*, **433**, 145-154. [https://doi.org/10.1016/s0003-2670\(00\)01379-9](https://doi.org/10.1016/s0003-2670(00)01379-9)