Geochemistry dataset of the Sol Hamed Neoproterozoic ophiolitic serpentinites, southern Eastern Desert, Egypt

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A B S T R A C T

The Sol Hamed (SH) area is a part of the Arabian-Nubian Shield (ANS) ophiolites occurred within Onib-Sol Hamed suture zone in the southern Eastern Desert of Egypt. The ophiolitic assemblages in this area are represented by serpentinite, metagabbro and arc assemblages represented by metavolcanics. They later intruded by gabbros and granites. The compatible trace elements (Cr = 2426 –2709 ppm, Ni = 1657–2377 ppm and Co = 117–167 ppm) enrichment in SH serpentinites indicate derivation from a depleted mantle peridotite source. They show affinity to the typical metamorphic peridotites. The normative compositions reflect harzburgitic mantle source. Their Al2O3 contents (0.05–1.02 wt %) are akin to oceanic and active margin peridotites and Pan-African serpentinites. The Cr and TiO2 contents indicate supra-subduction zone (SSZ) environment. Their Al2O3/SiO2 and MgO/SiO2 ratios support the SSZ affinity and are similar to ANS peridotites with fore-arc setting. Moreover, their Al2O3 and CaO depletion is typical of fore-arc peridotites.

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The data set of this article provides informations on the abundance of the Neoproterozoic serpentinites and its affinity. The Figs. 1–7, representing the geochemical analysis interpretation of the serpentinites, Fig. 8 representing comparing between SH serpentinite and others. Fig. 9 show geologic map of the area and also sample location. Fig. 10 represent photo for the serpentinites outcrops in the field. Table 1 represent the raw data of the major and trace element of the rocks. Table 2 represent the co-ordination of the samples.

2. Experimental design, materials, and methods

Ten representative rock samples from SH serpentinites were analyzed for major and trace elements. The analyses were carried out using a Philips X-ray fluorescence equipment model PW/2404, with Rh radiation tube and eight analyzing crystals. Crystal (LIF–200) was used for analyzing Ca, Fe, K, Ti and Mn; crystal (TIAP, PX–1) for Mg and Na; crystal (Ge) for P; and crystal (PET) for Si and Al. The concentration of the analyzed elements was determined using Super-Q software with accuracy 99.5% and confidence limit 95.6%. These chemical analyses were carried out at Central Laboratories of Egyptian Mineral Resource Authority (EMRA). The samples were cleaned and grinded in an electric agate mill, homogenized, and dried on the oven for 60 min at 105°C then mix with 50% from wax/polyvinyl metaaclylate additive.

3. Sample collections

Serpentinites samples were collected from some rock outcrops within area, ten (10) samples in total with their GPS coordinates recorded in Table 2. These samples were pulverized then filtered using sieve in order to remove pebbles and other irrelevant materials which may affect the result during the analysis. These samples were then packaged in to neat polyethylene bags and labelled orderly for identification.
4. Geochemistry of serpentinites

The MgO content is hardly affected by serpentinization process and its elevated values in SH serpentinites ($\text{MgO} = 43.83$–$45.71 \text{ wt} \%$) reflect highly depleted mantle source. Their high Mg# (89.94–92.85) are like modern oceanic peridotites indicating a limited mobility of Mg and Fe. Their very low Na$_2$O (0.00–0.28 wt %) and K$_2$O (0.00–0.06 wt %) contents are comparable to those from the Eastern Desert supporting this implication [6,7]. The serpentinitization processes possibly increased the LOI contents without significant modification of the major element composition. The Ca–metasomatism is a common issue in Egyptian serpentinites, however the very low CaO contents (0.05–0.75 wt %) in the serpentinites indicates restricted effect of carbonate metasomatism. So, we
suggest that the protolith major element compositions must have been preserved during the hydration processes and that the geochemistry of the serpentinites display mostly the original nature.

SH serpentinites display affinity to the typical metamorphic peridotites on the AFM diagram (Fig. 1) [1]. The bulk-rock Al$_2$O$_3$ content is relatively unaffected by serpentinization and therefore retains its original primary signature (Fig. 2) [2]. They have Al$_2$O$_3$ contents (0.05–1.02 wt %) comparable to oceanic and active margin peridotites and fore-arc and Pan-African serpentinites (Fig. 2) [2,3,6,7]. Like other Eastern Desert ultramaftes, the SH serpentinites have SiO$_2$/MgO ratios and Al$_2$O$_3$ contents analogous to ophiolitic peridotite (Fig. 3) [4–7]. The Al$_2$O$_3$ and CaO depletion is typical of fore-arc peridotites (Fig. 4) [8] and characterizes ED ophiolitic ultramaftes [5–7]. In terms of Al$_2$O$_3$/SiO$_2$ and

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**Fig. 3.** SiO$_2$/MgO ratios vs. Al$_2$O$_3$ diagram. Ophiolitic peridotite, ophiolitic gabbro and MORB are [4]. Data from Eastern Desert (ED) are shown for comparison [5–7].

**Fig. 4.** CaO vs. Al$_2$O$_3$ diagram showing SH serpentinites compared with fore-arc and MOR peridotites [8].
MgO/SiO₂ ratios, they are like Arabian–Nubian shield and fore-arc peridotites (Fig. 5) [5–7]. The serpentinites have enriched compatible trace elements (Cr = 2426–2709 ppm, Ni = 1657–2377 ppm and Co = 117–167 ppm) suggesting derivation from a depleted mantle peridotite source.

5. Alteration and serpentinization

Metamorphism ranging from low-grade greenschist to medium-grade amphibolite facies usually influenced the ophiolitic ultramafites of the Egyptian ED forming serpentinite and/or mixtures of serpentine, talc, chlorite, carbonates and magnetite [6,7]. The time and source of carbonate metasomatism that commonly affected the Egyptian ultramafites still debated.

Even with changes occurred during serpentinization in the mineral compositions of peridotites, geochemical data of serpentinites suggest negligible modification of major elements (except for Ca) at the hand-specimen scale. Therefore, the low CaO contents (0.05–0.75 wt %) in the serpentinites

![Fig. 5. MgO/SiO₂ vs. Al₂O₃/SiO₂ diagram. Primitive and depleted mantle values are after [9], respectively. The “terrestrial array” represents the bulk silicate Earth evolution [10]. Abyssal and fore-arc peridotite fields are after [11]. ANS ophiolitic peridotite field is after [6].](image)

![Fig. 6. Cr vs. TiO₂ plot to discriminate SSZ and MORB ophiolites after [12].](image)
indicate restricted effect of Ca–metasomatism. The CaO contents are not correlated with LOI further confirming this implication. Moreover, the trace element compositions (except U and Sr) are not significantly modified during serpentinization. Accordingly, the major and trace element data reflect the primary signature of the serpentinites protolith in subduction zones.

6. Geotectonic implications

The MgO/SiO$_2$ and Al$_2$O$_3$/SiO$_2$ ratios of serpentinites agree with SSZ peridotites from fore-arc setting (Fig. 5). Generally, the Al$_2$O$_3$ and CaO depletion characterizes fore-arc peridotites [8]. The Cr vs. TiO$_2$ diagram also supports the SSZ setting for the SH serpentinites (Fig. 6) [12].

Comparing SH ophiolites with other ophiolites such as, Troodos in Cyprus [15], Gerf ophiolite in South Eastern Desert [7] and Wadi Ghadir ophiolites in Central Eastern Desert [16]. Using the criteria in [12], we conclude that the chemical signature, the crystallization arrangement and mantle residue of
Fig. 9. Geologic map for SH area show the sample location.
**Fig. 10.** Field Photograph show the outcrop of the serpentinites.

| Table 1 | Major and trace elements of the studied rocks. |
|---------|------------------------------------------------|
| Sample no | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Major oxides (wt. %) | | | | | | | | | | |
| SiO₂ | 45.699 | 46.286 | 45.709 | 45.539 | 45.957 | 45.654 | 44.360 | 44.050 | 44.857 | 47.617 |
| TiO₂ | 0.057 | 0.056 | 0.011 | 0.058 | 0.012 | 0.023 | 0.023 | 0.023 | 0.035 | 0.012 |
| Al₂O₃ | 0.550 | 0.993 | 0.491 | 0.465 | 0.966 | 0.231 | 1.015 | 0.915 | 0.346 | 0.115 |
| Fe₂O₃ | 7.788 | 8.365 | 7.771 | 9.294 | 9.099 | 9.379 | 9.249 | 9.954 | 8.660 | 6.924 |
| MnO | 0.103 | 0.089 | 0.114 | 0.081 | 0.092 | 0.173 | 0.056 | 0.034 | 0.104 | 0.104 |
| MgO | 45.470 | 43.832 | 45.709 | 44.261 | 44.575 | 44.063 | 44.778 | 44.863 | 45.226 | 45.182 |
| CaO | 0.218 | 0.134 | 0.171 | 0.290 | 0.196 | 0.203 | 0.160 | 0.750 | 0.046 | |
| Na₂O | 0.103 | 0.011 | 0.058 | 0.000 | 0.012 | 0.000 | 0.034 | 0.000 | 0.012 | 0.000 |
| K₂O | 0.011 | 0.056 | 0.011 | 0.000 | 0.012 | 0.000 | 0.034 | 0.000 | 0.012 | 0.000 |
| Total | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

| Trace elements (ppm) | | | | | | | | | | |
| V | 40.200 | 25.900 | 27.400 | 37.200 | 26.100 | 22.160 | 40.200 | 14.010 | 34.100 | 19.500 |
| Cr | 2655.400 | 2701.100 | 2706.600 | 2656.800 | 2688.800 | 2580.200 | 2701.200 | 2654.100 | 2708.600 | 2425.900 |
| Ni | 2377.100 | 1800.300 | 2056.300 | 2057.300 | 2070.100 | 1840.200 | 1816.200 | 2055.400 | 1657.200 | 1999.100 |
| Cu | 63.100 | 15.100 | 24.100 | 30.530 | 43.210 | 53.210 | 54.210 | 152.400 | 154.200 | 136.100 |
| Zn | 56.900 | 13.460 | 24.900 | 23.070 | 35.100 | 17.900 | 34.800 | 17.200 | 11.890 | 23.050 |
| Co | 166.500 | 121.400 | 120.500 | 162.300 | 165.200 | 152.400 | 154.200 | 152.400 | 117.200 | 136.100 |
| Ga | 1.560 | 1.050 | 0.900 | 1.300 | 1.200 | 1.110 | 1.200 | 1.400 | 1.330 | 1.340 |
| Rb | 0.330 | 0.350 | 0.500 | 0.400 | 0.450 | 0.500 | 0.450 | 0.350 | 0.300 | 0.280 |
| Sr | 55.020 | 46.150 | 47.900 | 62.100 | 60.100 | 72.110 | 50.100 | 88.990 | 48.080 | 48.100 |
| Zr | 120.000 | 118.000 | 127.000 | 119.000 | 121.000 | 120.000 | 123.000 | 122.000 | 121.000 | 118.000 |
| Nb | 0.100 | 0.090 | 0.085 | 0.100 | 0.100 | 0.100 | 0.100 | 0.090 | 0.080 | 0.100 |
| Ba | 35.600 | 15.100 | 25.000 | 15.120 | 19.800 | 17.110 | 16.430 | 45.040 | 20.000 | 29.500 |
| La | 0.100 | 0.100 | 0.100 | 0.100 | 0.100 | 0.100 | 0.100 | 0.100 | 0.100 | 0.100 |
| Ta | 0.085 | 0.085 | 0.085 | 0.085 | 0.085 | 0.085 | 0.085 | 0.085 | 0.085 | 0.085 |
| Pb | 4.800 | 13.140 | 16.100 | 15.100 | 16.900 | 19.900 | 17.100 | 46.600 | 24.050 | 14.700 |
| Th | 0.200 | 0.200 | 0.200 | 0.200 | 0.200 | 0.200 | 0.200 | 0.200 | 0.200 | 0.200 |
| Tl | 0.037 | 0.038 | 0.040 | 0.030 | 0.026 | 0.040 | 0.038 | 0.040 | 0.300 | 0.280 |
| Li | 10.100 | 5.000 | 7.000 | 6.120 | 5.500 | 8.200 | 8.980 | 9.900 | 1.710 | 7.150 |
| Hf | 0.020 | 0.020 | 0.020 | 0.020 | 0.020 | 0.020 | 0.020 | 0.020 | 0.020 | 0.020 |
| Cs | 0.850 | 0.750 | 0.090 | 0.090 | 0.088 | 0.090 | 0.080 | 0.680 | 0.070 | 0.060 |
| Sn | 0.085 | 0.085 | 0.085 | 0.085 | 0.085 | 0.085 | 0.085 | 0.085 | 0.085 | 0.085 |
| Bi | 0.010 | 0.030 | 0.025 | 0.020 | 0.010 | 0.020 | 0.030 | 0.030 | 0.025 | 0.020 |
SH ophiolites are similar to supra-subduction zone ophiolites formed in fore-arc basins based on the Ti–V variation diagram [14], (Fig. 8).

7. Magma source

The samples show low Al$_2$O$_3$ content reflecting depleted upper mantle source. Their high Mg#, Cr and Ni are consistent with a depleted mantle peridotite source. The MgO/SiO$_2$ and Al$_2$O$_3$/SiO$_2$ ratios accord with peridotites generated from subduction-related magma source (Fig. 5).

8. Protolith primary signature

Numerous geochemical studies demonstrated restricted mobility of major elements during serpentinization and protolith primary signature were retained [11]. The SH serpentinites have low CaO contents comparable to ophiolitic peridotites [4]. Moreover, their low Al$_2$O$_3$/SiO$_2$ ratios (mostly < 0.03) are similar to fore-arc mantle wedge serpentinites suggesting that their protolith had experienced partial melting before serpentinization which has no effect on this ratio. Also, their low MgO/SiO$_2$ ratios (<1.1) resemble serpentinised lherzolites and harzburgite. They have low TiO$_2$ contents (0.01–0.06 wt %) compared to depleted mantle composition but like subduction zone serpentinites. Their major element data consistent with harzburgitic source (Fig. 7).

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Table 1 (continued)

| Sample no | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 |
|-----------|----|----|----|----|----|----|----|----|----|----|
| Cd        | 2.100 | 2.100 | 3.200 | 3.400 | 2.150 | 2.500 | 3.500 | 3.400 | 3.450 | 2.900 |
| In        | 0.010 | 0.010 | 0.010 | 0.010 | 0.010 | 0.010 | 0.010 | 0.010 | 0.010 | 0.010 |
| W         | 0.090 | 0.090 | 0.090 | 0.090 | 0.090 | 0.090 | 0.090 | 0.090 | 0.090 | 0.090 |
| Mo        | 0.010 | 0.010 | 0.010 | 0.010 | 0.010 | 0.010 | 0.010 | 0.010 | 0.010 | 0.010 |
| Re        | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 |
| Sb        | 1.830 | 2.400 | 3.110 | 1.140 | 3.150 | 2.700 | 3.100 | 3.100 | 1.980 | 2.330 |
| As        | 4.210 | 5.330 | 3.700 | 5.700 | 5.300 | 4.800 | 4.500 | 5.210 | 4.910 | 3.800 |
| Ag        | 185.000 | 190.000 | 195.000 | 191.000 | 187.000 | 170.000 | 193.000 | 192.000 | 190.000 | 194.000 |
| S         | 0.040 | 0.040 | 0.040 | 0.040 | 0.040 | 0.040 | 0.040 | 0.040 | 0.040 | 0.040 |
| Se        | 0.300 | 0.500 | 0.400 | 0.300 | 0.700 | 0.230 | 0.300 | 0.400 | 0.700 | 0.500 |
| Be        | 0.850 | 0.700 | 0.900 | 0.850 | 0.900 | 0.900 | 0.800 | 0.700 | 0.700 | 0.800 |
| Te        | 5.500 | 5.400 | 5.500 | 5.500 | 4.110 | 4.800 | 5.700 | 4.300 | 4.980 | 5.120 |
| Rb        | 1.810 | 1.000 | 1.200 | 1.700 | 1.450 | 0.330 | 0.800 | 0.200 | 0.200 | 1.300 |
| Sc        | 4.100 | 4.010 | 3.800 | 3.550 | 4.200 | 3.700 | 3.940 | 4.010 | 4.300 | 3.900 |
| U         | 0.090 | 0.090 | 0.090 | 0.090 | 0.090 | 0.090 | 0.090 | 0.090 | 0.090 | 0.090 |

Table 2

The sample location of SH serpentinites.

| Sample Code | Longitude | Latitude |
|-------------|-----------|----------|
| SH 01       | 36° 10’ 35.83” | 22° 19’ 13.83” |
| SH 02       | 36° 08’ 23.35” | 22° 17’ 14.57” |
| SH 03       | 36° 11’ 16.68” | 22° 19’ 04.75” |
| SH 04       | 36° 10’ 21.00” | 22° 18’ 41.50” |
| SH 05       | 36° 08’ 01.49” | 22° 16’ 38.41” |
| SH 06       | 36° 09’ 59.28” | 22° 17’ 25.84” |
| SH 07       | 36° 08’ 47.10” | 22° 17’ 18.11” |
| SH 08       | 36° 09’ 44.93” | 22° 17’ 25.51” |
| SH 09       | 36° 09’ 54.64” | 22° 18’ 07.03” |
| SH 10       | 36° 07’ 29.67” | 22° 16’ 12.07” |
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**Conflict of interest**

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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