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Geochemistry of the Precambrian Granitoids of Wadi El-Rahaba Area, South Sinai, Egypt

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ABSTRACT. Two groups of granitic rocks are exposed in the Wadi El-Rahaba area: the older of which is chemically metaluminous, depleted in Nb and subduction related, whereas the younger is metaluminous to peraluminous, enriched in Nb and intraplate, an orogenic granite formed through partial melting of lower crustal materials.

The present paper deals with the geochemistry of the granitic rocks cropping out in the Wadi El-Rahaba area, south Sinai (Fig. 1). The geology and petrography of these granitic rocks have been recently studied by Habeab (1989). These granitic rocks comprise two groups. The older group consists of quartz diorites, tonalites and granodiorites that are traversed by mafic dykes and contain many rounded xenoliths. They are deeply eroded giving rise to hilly outcrops that are topographically lower than the younger granites. The younger granites form mountain masses and ridges of biotite monzogranites with pronounced pink colour and are cut by numerous dykes. No isotopic ages are available for these rocks.

Twenty rock samples of the older and younger granitoids from Wadi El-Rahaba area, were analysed for major and selected trace elements. SiO_2, Al_2O_3, CaO, MgO, MnO, K_2O, Fe_2O_3 and TiO_2 were determined by XRF (Model PW 1540), FeO was determined by titration with K-dichromate, Na_2O by flame photometry, and P_2O_5 by atomic absorption. The trace elements were determined by X-ray fluorescene (XRF). All the analysis were carried out in the laboratories of the Egyptian Nuclear Materials Corporation, Cairo. The results along with

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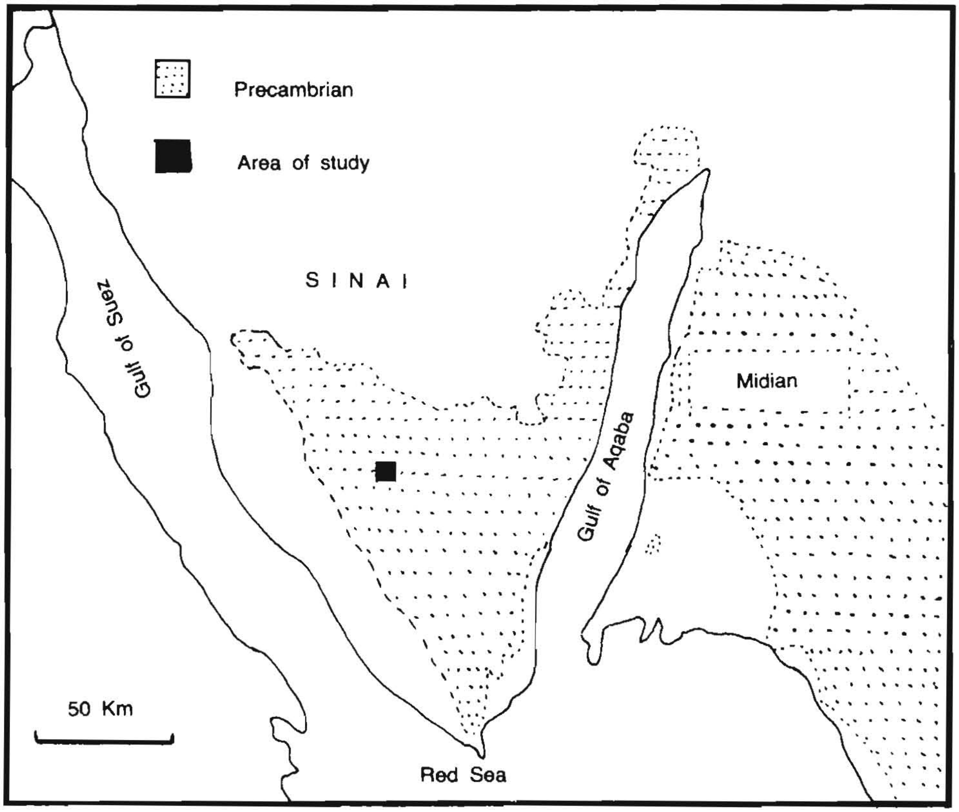

Fig. 1. Location of Wadi El-Rahaba area.

averages for corresponding rocks from the Midian region of the northwestern Arabian Shield of the Kingdom of Saudi Arabia reported by Ramsay *et al.* (1986), are given in Tables (1 and 2).

Element Distribution

Both older and younger granitoid intrusions of Wadi El-Rahaba have a wide range of chemical composition. This is reflected, for example, in the wide variation of CaO contents in each intrusion, which ranges from 2.56 to 5.92% for the older intrusion and from 0.38 to 2.81% for the younger intrusion. This may reflect the multiphase nature of each intrusion (*i.e.*, each instrusion is formed by more than one phase).

A Comparison of the older granitoids of Wadi El-Rahaba with the Ifal suite which represents the oldest granitic rocks (625 Ma) in the Midian region of the

Saudi Arabia reported by Ramsay *et al.* (1986) is given in Table (1). From this table it can be concluded that the Wadi El-Rahaba older granitic rocks have higher CaO, MgO, FeO, and Ba and lower SiO_2, TiO_2, Na_2O, Rb, Sr, Y, Nb and Zr values than their comparable rocks. On comparing the younger granites of Wadi El-Rahaba with the Atiyah monzogranites (599 ± 5 Ma) of the Midian region (Table 2), it is noticeable that the younger granites under investigation are relatively enriched in Rb, Zr, Ba and Nb and depleted in Sr and contain nearly equal amounts of major elements with respect to the reference granites.

Table 1. Chemical analyses of the older granites

Sp. No.	1	2	3	4	5	6	Average	Ramsay *et al.* (1986)
SiO_2	66.10	64.21	66.33	67.38	67.87	69.41	66.88	69.05
TiO_2	0.37	0.65	0.33	0.35	0.25	0.37	0.39	0.46
Al_2O_3	14.30	14.18	16.21	14.41	13.98	13.68	14.46	14.80
Fe_2O_3	2.11	2.22	1.98	2.09	1.11	1.37	1.81	1.72
FeO	3.06	3.14	2.11	2.31	0.83	0.88	2.06	1.26
MnO	0.04	0.15	0.06	0.02	0.05	0.04	0.06	0.06
MgO	2.41	2.14	1.79	1.96	2.02	1.03	1.89	1.16
CaO	3.52	5.78	2.56	2.63	5.92	3.33	3.96	2.18
Na_2O	3.88	3.88	4.31	4.18	4.21	4.00	4.08	4.51
K_2O	2.90	2.58	3.33	3.60	2.20	4.48	3.18	3.68
P_2O_5	0.04	0.06	0.04	0.04	0.05	0.05	0.05	0.14
H_2O^-	0.19	0.22	0.19	0.11	0.26	0.12	0.18	–
H_2O^+	0.83	0.50	0.54	0.61	0.81	0.77	0.68	0.75
Total	99.75	99.71	99.78	99.69	99.56	99.53	99.68	99.77
MDI	8.56	6.65	10.09	10.33	7.22	11.43	9.05	
Weight norms :								
Q	20.28	17.47	19.94	20.28	23.35	21.29	20.44	22.96
Or	17.60	15.30	19.70	21.40	12.75	26.90	18.94	21.96
Ab	36.10	35.40	39.10	37.75	37.40	36.50	37.04	38.53
An	8.85	14.03	6.20	6.50	12.90	6.22	9.12	9.36
Cor	0.75	– –	3.59	1.47	– –	– –	0.97	– –
Trace elements (ppm) :								
Rb	60	80	43	80	43	70	62.6	92
Sr	260	250	302	290	260	260	270.3	400
Y	15	12	10	9	14	13	12.1	20
Ba	550	688	930	1031	550	550	716.5	673
Nb	7	8	4	5	3	9	6	13
Yb	2	4	4	6	3	5	4	–
Zr	142	120	129	160	120	137	134.6	183

Table 2 . Chemical analyses of the younger granites

Sp. No.	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Average	Ramsay et al. (1986)
SiO_2	74.00	74.37	75.13	75.56	71.85	73.41	70.36	74.06	70.00	74.39	75.14	69.66	74.46	75.11	73.39	73.24
TiO_2	0.09	0.13	0.15	0.14	0.29	0.17	0.24	0.21	0.37	0.15	0.23	0.24	0.09	0.12	0.19	0.26
Al_2O_3	13.61	12.86	12.54	13.11	13.50	13.30	14.65	13.22	13.59	13.06	13.09	15.26	12.96	13.21	13.42	13.90
Fe_2O_3	0.43	1.22	0.91	0.62	0.76	0.56	1.80	0.73	1.21	0.77	0.71	1.53	0.52	0.52	0.88	0.97
FeO	0.67	0.42	0.71	0.50	0.58	0.43	0.95	0.88	2.12	0.92	0.63	0.90	0.46	0.43	0.76	0.70
MnO	0.04	0.02	0.04	0.05	0.05	0.04	0.04	0.03	0.05	0.03	0.02	0.06	0.04	0.05	0.04	0.06
MgO	0.17	0.29	0.13	0.21	0.80	0.59	1.34	0.32	0.63	0.44	0.36	1.26	0.48	0.40	0.53	0.39
CaO	1.98	1.12	1.47	0.44	2.38	1.66	2.30	1.60	2.81	0.38	0.52	2.27	1.86	0.81	1.54	1.14
Na_2O	4.21	3.69	3.37	3.71	3.48	3.71	3.88	3.50	3.98	4.02	3.80	3.54	4.04	4.31	3.80	4.29
K_2O	3.41	4.99	482	4.33	5.13	5.08	4.14	4.21	4.18	4.91	4.52	4.76	4.15	4.12	4.52	4.22
P_2O_5	0.03	0.02	0.03	0.03	0.03	002	0.02	0.05	0.04	0.03	0.04	0.02	0.03	0.03	0.03	0.07
H_2O^-	0.22	0.22	0.09	0.22	0.08	0.08	0.11	0.27	0.22	0.26	031	0.18	0.15	0.09	0.18	–
H_2O^+	0.44	0.44	0.33	0.63	0.69	0.77	0.29	0.65	0.81	0.30	0.41	0.35	0.50	0.35	0.50	0.62
Total	99.80	99.79	99.72	99.55	99.62	99.82	100.12	99.73	100.01	99.66	99.78	100.03	99.74	99.55	99.78	99.86
MDI	13.15	14.63	14.50	14.80	12.94	15.15	11.07	13.54	11.88	14.72	14.74	11.50	13.30	14.90	13.58	
Weight norms :																
Q	29.26	30.01	32.84	34.65	25.63	27.47	22.14	32.91	23.38	28.85	32.60	21.46	29.68	30.53	28.67	29.48
Or	23.45	30.10	29.00	26.15	30.85	30.55	24.50	25.35	24.95	29.35	27.20	28.25	24.85	24.50	27.10	25.07
Ab	38.10	33.75	30.70	33.85	31.70	33.70	35.00	31.95	36.30	36.70	34.60	31.85	36.70	39.20	34.58	36.58
An	4.85	2.75	3.63	1.05	5.85	4.00	5.60	3.82	6.98	0.92	1.15	5.50	4.57	1.88	3.75	5.24
Cor	0.75	0.43	0.54	2.20	–	0.26	1.86	1.78	0.06	0.88	1.68	1.53	0.26	1.10	0.95	0.38
Trace Elements (ppm) :																
Rb	161	108	117	132	108	108	216	110	95	120	101	180	188	104	132	111
Sr	44	52	65	80	130	130	26	90	89	91	39	91	52	52	73.6	152
Y	21	17	19	13	13	9	17	43	13	17	26	17	17	19	18.6	18
Zr	160	170	165	137	171	137	341	512	125	154	137	171	170	143	192.3	148
Ba	608	550	520	344	629	864	275	275	786	491	864	629	138	530	536	493
Nb	20	30	50	25	33	22	35	20	44	30	45	50	55	45	36	17
Yb	5	6	8	5	10	6	7	7	8	6	8	6	7	4	6.6	–

All the analysed samples, except one sample from the older granitoid (sample no. 5) have K_2O/Na_2O, > 0.60. According to Raguin (1965) these rocks have potassic character, whereas sample no. 5 is sodic.

Petrogenesis and Tectonic Environment

The normative O, Or, Ab proportions of the studied granitic rocks are plotted and the results compared with experimental data of Tuttle and Bowen (1958) (Fig. 2). It is observed from this figure that both intrusions fall in a rather limited region around the minimum melting curve with no overlap between them. The majority of the younger granite samples and one sample from the older intrusion are slightly more potassic than the other samples. The older intrusion samples plot at the high water vapour pressure end of the minimum melting composition. Such a high

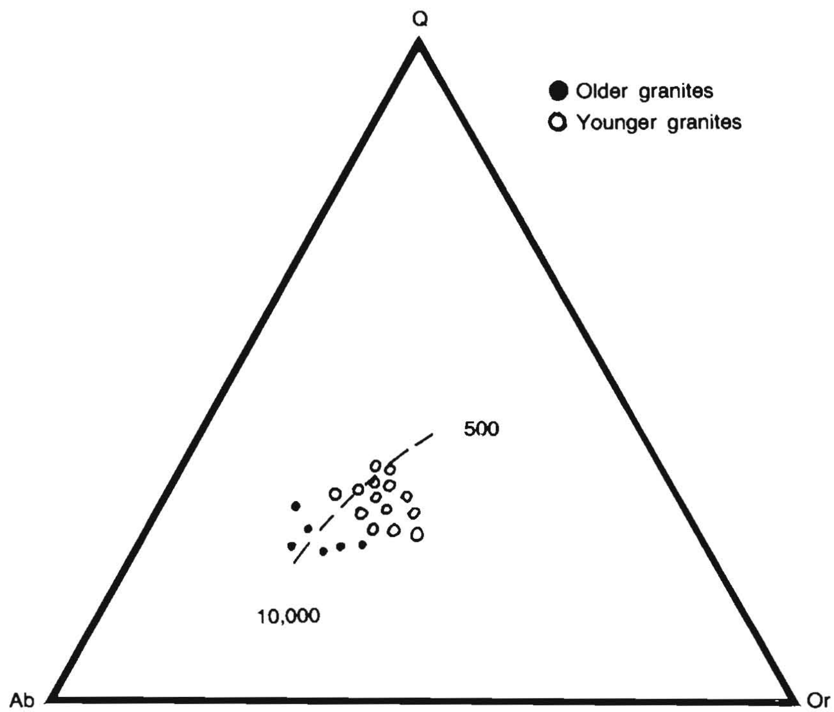

Fig. 2. Normative Q-Or-Ab proportions for the investigated granitic rocks. The solid line represents the variation in position of the minimum melting points in the granite system at water vapour pressures from 500 to 10,000 bars (after Tuttle and Bowen 1958).

P_{H_2O} in turn, suggests that the batholith was formed from hydrous melts. More likely hydrous calc-alkaline melts are associated with hydrous subduction zone melting. Whereas the younger intrusion samples have their composition close to the moderate to low water-vapour pressure end in the granite system suggesting that these rocks were formed through relatively unhydrous zone melting. El-Gaby (1975) and Zaghloul *et al.* (1976) have shown that the field composition of some of the Egyptian younger granites is close to the minimum melting point at low to moderate pressures in the granite system of the Tuttle and Bowen (1958). According to them these granites are considered to be largely intruded as palingentic magmas, and the early phases of these magmas were formed at higher water-vapour pressure, while the later phases were formed under progressively decreasing water-vapour pressures.

The analysed samples, except one sample from the older granitoids (sample no. 3) are metaluminous (A/CNK, *i,e.*, mol. $Al_2O_3/(CaO+Na_2O+K_2O) < 1$, Shand, 1951). The younger granites comprise metaluminous (A/CNK < 1) and peraluminous (A/CNK > 1) varieties.

On plotting the SiO_2 values versus log K_2O/MgO of the granitoids under investigation (Fig. 3). A big gab is observed between the two groups of granite, and the younger granites fall in the "crustal-related" or alkali granite field, whereas most samples from the older granitoids fall in the subduction-related or calc-alkaline batholiths as defined by Rogers and Greenberg (1981).

Nb is regarded by many granite specialists as a critical element. On plotting Nb versus Y of the studied granitoids in the Pearce *et al.* (1984) tectonic environment fields diagram (Fig. 4). Ii is clear that the two groups of granite are separated by a big Nb gap, whereas Y abundances overlap, and the older granitoids fall in the syn-collision granites field (relatively depleted in Nb) and the younger granites plot along the boundary between the volcanic-arc granites and the within plate granites field (relatively enriched in Nb).

The conclusions reached from the foregoing discussion become clear, however, when plotting Nb versus SiO_2 (Fig. 5). This plot was used by Pearce and Gale (1977) to distinguish between low Nb magmas generated above Benioff zone and high Nb, within plate magmas. Figure 5 plots the Wadi El-Rahaba date in this diagram. It is clear that the two groups of granites are significantly different and plot in two different fields viz, the subduction-related field and the within plate field. However, it is tentatively suggested here that the older granitoids probably generated above Benioff zone, through partial melting of mantle wedge with little or no crustal melt contribution and the younger granites are intraplate, anorogenic granites formed by melting of crustal rocks. Sr Isotope studies are needed to confirm this conclusion.

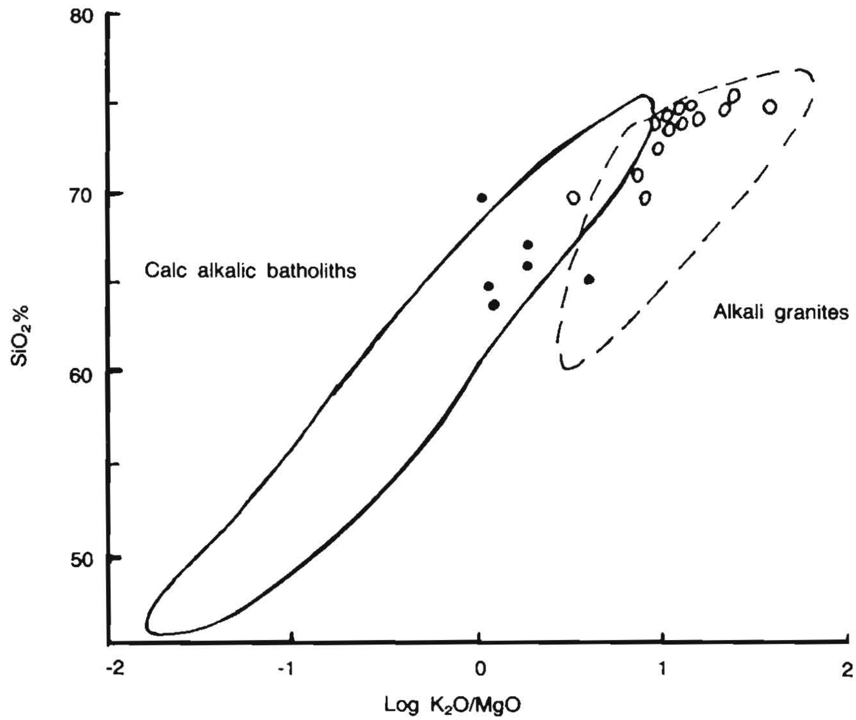

Fig. 3. SiO_2 versus log K_2O/MgO plot of the investigated granitic rocks. The fields are after Rogers and Greenberg (1981). Symbols as in Fig. 2.

Conclusion

The older granitoid rocks of Wadi El-Rahaba area are dioritic to granodioritic in composition, enriched in CaO, MgO, FeO and Ba and depleted in SiO_2, Na_2O, TiO_2, Rb, Sr, Y, Nb and Zr relative to the older granitic rocks of the Midian region of Saudi Arabia. The younger granitoids are granitic in composition and are enriched in Rb, Zr, Ba and Nb and depleted in Sr and contain nearly equal amounts of major elements with respect to the younger granites of Midian region. The older granitic rocks are depleted in Nb relative to the younger group and are subduction related. The younger granites are intraplate, anorogenic granites, formed through partial melting of crustal rocks.

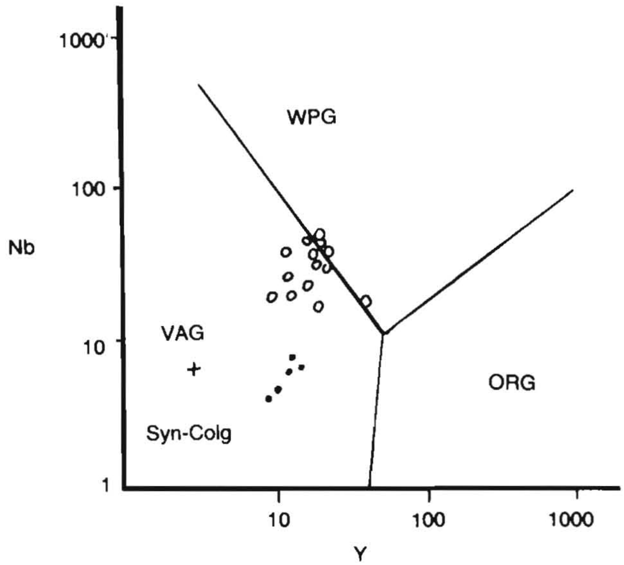

Fig. 4. Nb versus Y plot of the wadi El-Rahaba granitic rocks. Field names: (VAG) volcanic arc granites; (syn-COLG) syn-collision granites; (WPG) within plate granites; and (ORG) ocean ridge granites. (after Pearce *et al.* 1984). Symbols as in Fig. 2.

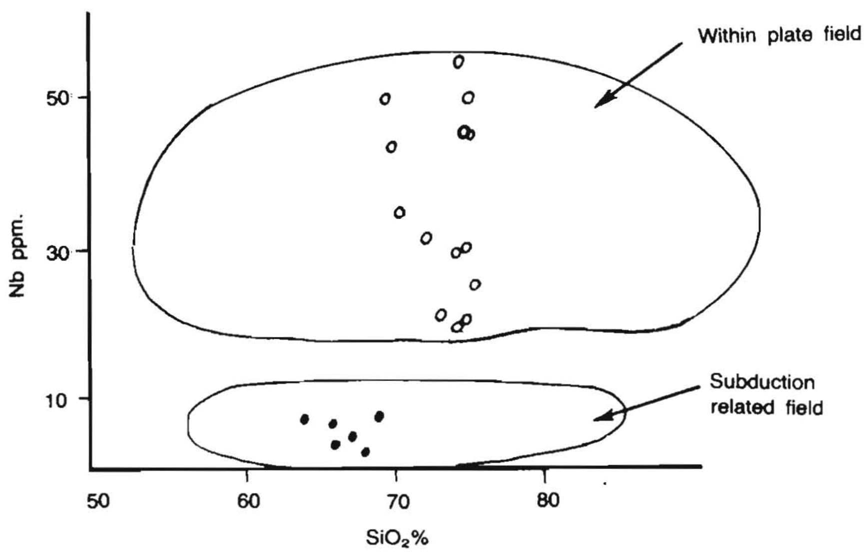

Fig. 5. Nb versus SiO_2 plot of the investigated granitic rocks. Symbols as in Fig. 2.

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جيوكيميائية صخور الجرانيت البريكامبرية في وادي الرحبة بجنـــوب سينـــاء ـ مصـــر

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يختص هذا البحث بدراسة جيوكيميائية ونشأة المتداخلات الجرانيتية الواقعة في منطقة وادي الرحبة بجنوب سيناء وقد بينت الدراسة وجود نوعين من المتداخلات الجرانيتية، تتكون المتداخلة الأقدم من كوارتز دايورايت وتوناليت وجرانود يورايت، وقد تداخلت في حشد من صخور النايس والجابرو ـ دايوريت، وتتكون المتداخلة الأحدث من جرانيت وردي اللون تقطع صخور المتداخلة الأقدم وصخور الجابرو والدايورايت، وتخترق صدوع خليج السويس وخليج العقبة كلا المتداخلتين.

وقد ثبت من التحليل الكيمائي أن لصخور المتداخلة الأقدم خواص جيرقلوية وربما تكونت في بيئة غوض وانزلاق فوق نطاق بينوف بانصهار مواد من الستارة مع أو بدون إضافات من صخور القشرة الارضية أما صخور المتداخلة الأحدث فلها صفات قلوية وقد تكونت بالانصهار الجزئي لصخور القشرة الارضية أو ربما نتيجة وخلال تسييل وانصهار صخور المتداخلة الأقدم وذلك في بيئة داخل اللوح، أي أنها غير مرتبطة بعملية بناء الجبال وحركة الالواح التكتونيه.

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