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REES-BEARING LATERITES, WADI NATASH, SOUTHEASTERN DESERT, EGYPT

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ABSTRACT

Volcanic rocks of the Wadi Natash are located ~ 70 Km, east of Kom Ombo (south Eastern Desert of Egypt), about 120 Km, ENE of Aswan and covers about 500 Km^2 The present paper records for the first time the occurrence of laterites- bearing REEs in Natash volcanics. Natash volcanic rocks lie between the lower and upper Nubia sandstone, and are represented by Natash flows (alkali olivine basalt, basaltic- andesite, mugearites and benmoreites), volcaniclastic sediments (agglomerates, lapillistones & laminated tuffs) and less common trachytes and rhoylites.

Natash laterite deposits occur as horizons (5 -15 m. thickness) at the boundary between the two Cretaceous sandstones, superimpose on the top of Natash flows and at the base of volcaniclastic sediments. Laterite was recorded in more than twenty six occurrences distributed over an area of about 500 Km^2 along and around Wadi Natash. It ranges in color from light-grey, dark-grey to reddish-brown. The distribution of laterite deposits is structural controlled (NW-SE and NE-SW faults).

Mineralogical results of laterites proved the presences of both kaolinite and montmorillonite as clay minerals. The presence of hyperthene, diopside and tremolite in laterites indicate that, their main source was basic Natash flows. Xenotime, zircon, fluorite, apatite and allanite are the source of REEs in laterites. Xenotime – (Y) occurs with the highest Yb (564 -1132 ppm) and Dy (420 – 821 ppm) values. Gypsum, hematite, goethite, calcite and kaolinite indicate that, the Natash laterites are related to tropical weathering. The presence of ilmenorutile and rutile in the laterites declare the reducing and low pH conditions during the formation of these deposits. The paleogeological conditions at Natash area favoured kaolinization and bauxitization over lateritization.

All the Natash laterite samples are characterized by very steep REE pattern with HREE enrichment. Generally, the$\sum$ REEs+Y grade, ranges from 0.36 % – 0.71 % (from reddish -brown to light and dark- grey laterites respectively) with an average of about 0.59 % (light-grey one) .The REE contents generally increased with increases in weathering. The LREE is less concentrated than the HREE by a factor of (0.57). $\sum$(LREE / HREE = 0.57) which suggests that, the HREE contents in laterites were derived from the basic and intermediate flows. The barren nature of Natash laterites –bearing REEs from any radioactive elements, in addition of their high contents of REEs, must lead to future evaluating of the reserves of the leachable laterites –bearing REEs.

Key words: Natash flows, laterites, clay minerals, REEs.

INTRODUCTION

Volcanic rocks of the Wadi (W.) Natash are located ~ 70 Km, east of Kom Ombo (south Eastern Desert of Egypt), about 120 Km, ENE of Aswan and covers about 500 Km^2. The volcanic rocks are intercalated with the Nubia sandstone. The volcanic rocks are separated from the metamorphic rocks by a thin layer of basal Nubia sandstone which lies non-conformably on the basement complex. Natash volcanics are located between Long. 33° 57′ 33″ – 34° 15′ 34″ E . and Lat. 24° 17′ 21″ – 24° 31′ 07″ N. (Fig. 1).

Many investigations have been published on Natash volcanics concerning the tectonic setting, geology, geochemistry, age determination and mineralogy (Barthaux, 1922, El Ramly et al., 1971; Abu El- Gadayel, 1974, Hashad &El Reedy, 1979, Hashad et al., 1982, Crawford, et., al., 1984, Almond, 1986a&b, Mohamed, 2001). Natash volcanic rocks lie between the lower and upper Nubia sandstone, and are represented by Natash flows (alkali olivine basalt, basaltic-andesite, mugearites and benmoreites) volcaniclastic sediments (agglomerates, lapillistones & laminated tuffs)(Fig.1) and less common trachytes and rhoylites .

Natash lavas have been dated at 90 Ma, Late Cretaceous age (Higazy and El- Ramly, 1960; El-Shazly and Krs, 1973; Hashad &El Reedy, 1979, Hashad et al., 1982). Therefore, the eruption of Natash lavas predates actual Red Sea rifting by about 60 Ma ago. Stratigraphically, Natash lavas are post basal Nubia, but prior to the upper parts of the Nubia (Hunting, 1967). The isotopic ages are also corroborated by Late Cretaceous leaflets found in the intercalated volcaniclastic sediments of Natash volcanics. Natash volcanic flows exhibit alkaline differentiation and have the composition of alkali olivine basalt to trachyte.

Crawford (1984) reported that the eruption of the Wadi Natash volcanics is belong to the intraplate, bimodal alkali-basalt suite and not related directly to the Red Sea rifting.

In Egypt the main rocks - bearing REEs are lamprophyre dykes (Abu-Rusheid area), monazites (black sands, coastal plain of the Med. Sea), carbonatites (El- Mansoury Ring), pegmatites (Abu Dob & Kadabora area), alkaline granites (Gara El -Hamra), acidic volcanics and associated pyroclastics (Um- Safi volcanics) and laterites (UM Bogma Formation, Sinai). Generally ,four modes of occurrence of laterites and bauxite materials are recorded by Shaffer, (1975) ; 1) blanket laterites ,which extend laterally for few hundreds of meters to several kilometers with thickness around 5 m., 2) pocket laterites, which occur as lenses within argillaceous sediments or masses of igneous and metamorphic rocks,3) deterital deposits and 4)interlayered deposits which are overlain by younger sedimentary rocks or volcanics . El- Aassy et, al., (2004) recorded at Um Bogma Formation, Sinai, the occurrence of REEs in both blanket and pocket laterites.

The present paper records for the first time the occurrence of laterites-bearing REEs in Natash volcanics, at the southeastern Desert of Egypt.

GEOLOGIC SETTING

Natash volcanics form dissected plateau with stratified appearance. The plateau is formed of thick piles of volcanic flows and their pyroclastics, as well as, trachytes and rhoylites. These piles appear as relics of adjacent former volcanoes. The volcanic sequence is represented by three distinct flow units, separated by sequences of volcaniclastic sediments. Each of flow these units shows a gradual change in composition upwards from a basal grey-green to olive porphyritic alkali olivine basalt layer that grades upward to vesicular black basalt (scoria)to a grey –green, generally porphyritic ,mugearites- benmoreite.

The lowest flow unit rests on the basal Nubia sandstone, while the upper Nubia units overlie the upper volcanic flows and volcaniclastic sediments. The latter start by basal agglomerates and fining upward to white, grey, red and maroon lapillistone and laminated tuffs bed. The agglomerates may occur as one or two layers (up to 8 m thickness) .They are composed of rounded pebbles and cobbles of flow debris in a coarse to sandy matrix of lithic fragment. The agglomerate layers are extended over

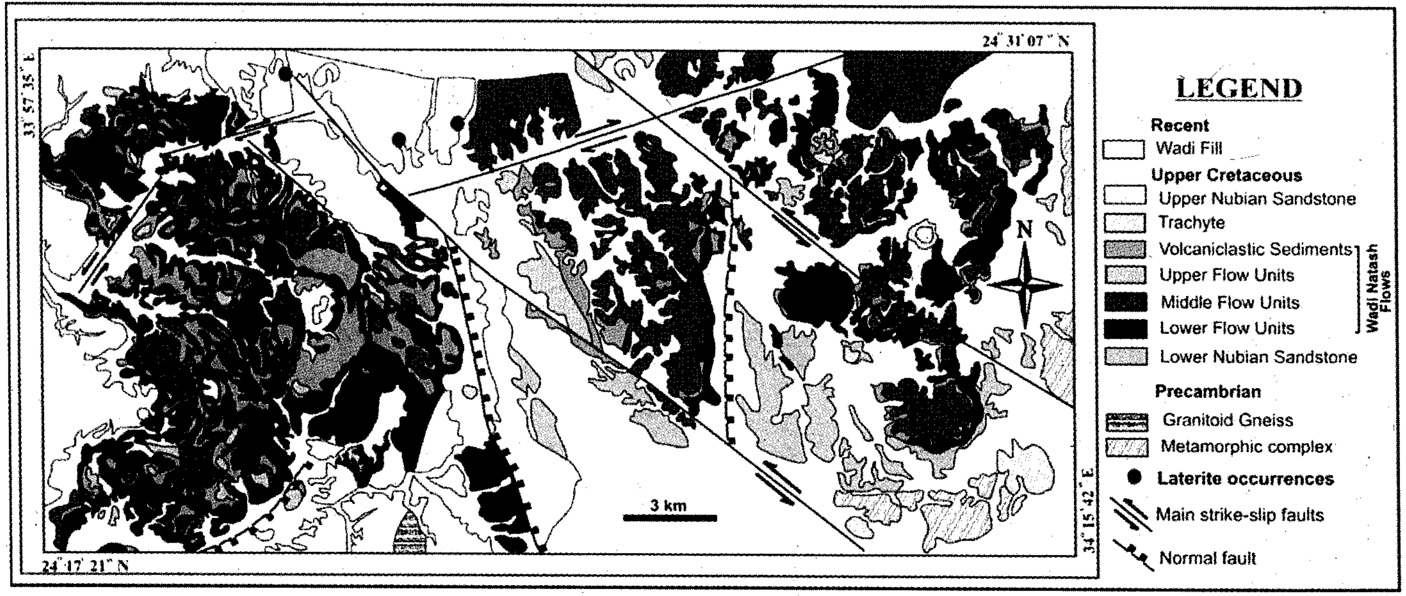
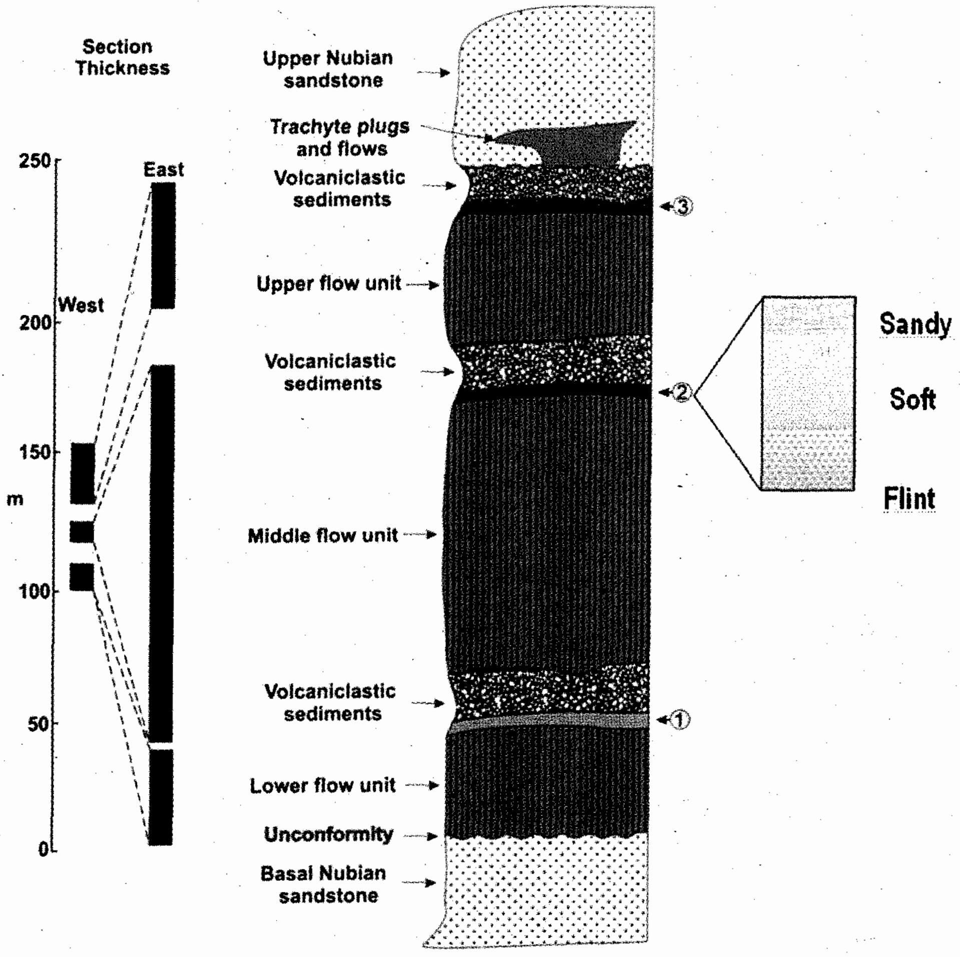


Fig (1): Geologic map of Wadi Natash, Southeastern Desert, Egypt, (modified after Crawford, 1984, 1984)



(Fig.2) Lithostratigraphic section of Natash volcanics (Modified after Crawford, 1984) and location of discovered laterites (1, 2& 3).

considerable areas and are not confined to a specific horizon. All the flow units (220 m thickness) and the associated volcaniclastic sediments (30m thickness) are generally thick to the east of Natash volcanics, whereas they tend to be thin to the west (35 m & 15 m respectively) (Fig. 2).Erosion has removed the upper flow and the upper volcaniclastic sequence from most location on the east (Crawford, 1984).

Two strike slip sets of faults are recorded (Fig. 1). The first set is the dominant and running NW-SE, showing different degrees of fault cataclases and breccias with left lateral movements. The second set of faults is the oldest and running NE-SW with, right lateral movement. All over the studied area, lava flow are horizontal or slightly inclined, with an angles ranging from 5^o – 12^o to WSW which can be related to the displacement along the youngest normal faults (N-S trends).

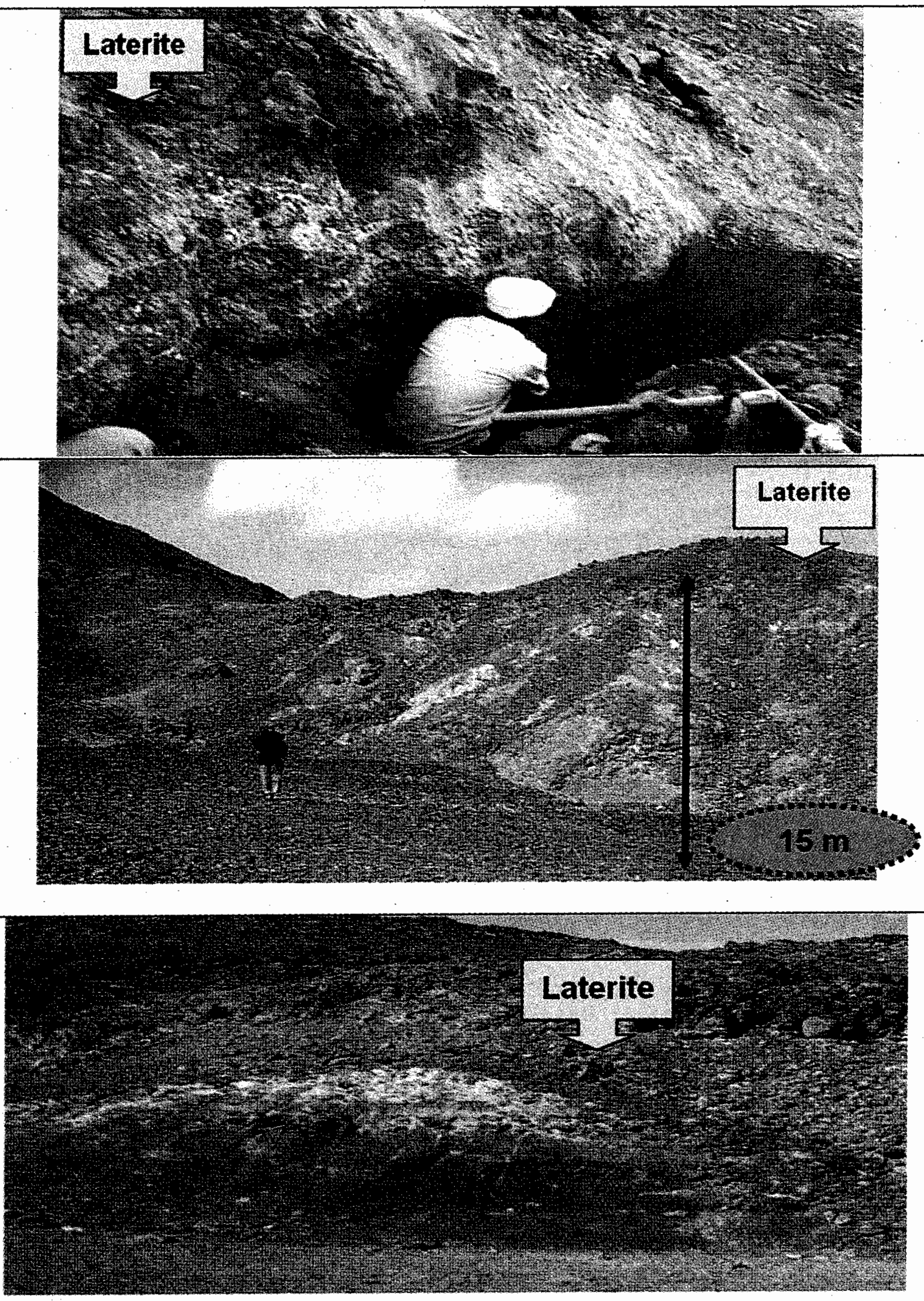
Laterite recorded at Natash area in more than twenty six occurrences, , between the lower and upper Nubia sandstone. Laterite overlies the Natash flows (olivine basalt, mugearites and benmoreite) and covered by the base of volcaniclastic sediments (agglomerates, tuffs) (Fig. 2). It ranges in color from dark-grey at the base, light-grey and reddish-brown at the top (Fig.3). It froms sandy kaolin at the base, soft kaolin at the intermediary portion grading to fine kaolin at the top (Fig. 3). Outcrops of laterite horizons in W. Natash are distributed over an area of about 200 Km^2 but have fairly uniform thickness averaging from 5 to 15 m above the W. level and extend in some outcrops for one kilometer in length depending on the topography and drainage patterns. The distribution of laterite deposits is structural controlled (NNW-SSE & ENE-SSW faults).Severe weathering can be noticed in many localities of Natash volcanics ,especially at the top of the basic flow units which may be as a result of cataclases and hydrothermal solution effects. From the environmental point of view, Natash laterite is barren of any radioactive elements.

MINERALOGY

ACIDIC FLOWS (TRACHYTES & RHOYLITES)

The separated minerals were examined by XRD and the Environmental Scanning Electron Microscope (ESEM) supported by qualitative energy dispersive spectrometer unit at the Nuclear Materials Authority (NMA) of Egypt. The mineralogical results for these separated mineral fractions from Wadi Natash trachytes and rhyolites samples reveal the presence of columbite, xenotime, metamict zircon, pyrite, fluorite, apatite, pyrophyllite and chaistolite minerals.

Columbite (Fe, Mn) $(Nb, Ta)_2O_6$ belongs to columbite-tantalite minerals series. The chemical composition of this series varies greatly even in the same deposition; the contents of Fe, Mn as well as of Nb and Ta vary within a wide range .The investigated columbite contains 48.6 % Nb, 11.9 % Y, 7.80 % Ta, 7.30 % Fe, 2.9 % Ti. These data indicate that it is enriched in Ta, where the ratio Nb/Ta = 6.2 indicates alkaline metasomtism.



Figs. (3): View showing laterite occurrences with color variations in lower lava flow, Wadi Natash, Southeastern Desert, Egypt.

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Xenotime (YPO_4) commonly contains small amount of REE (Er, Ce), sometimes Th, U (up to 5 %), Zr (up to 3 %), Sn and Si (up to 9 %). Xenotime in Natash acidic samples is usually uraniferous and containing 33.0 % Y, 8.8 % P, 8.5 % U and 49.1 % Fe.

Zircon crystals ($ZrSiO_4$) show different forms such as bipyramids, short prisms with terminated bipyramids. The zircon crystals are of primary and secondary origin. Zircon in Wadi Natash is mostly metamict, which is confirmed by XRD and ESEM. It contains 51.6 % Zr, 5.1 % U, 2.7 % Hf, 2.6 % Fe, 1.1 % Mn and .03% Ce.

Pyrite (FeS_2) contains 48.50 S %, 51.50 Fe %. It occurs in cubic crystals with pale brass-yellow color. Pyrite in the altered volcanics suffered from partially and/or completely oxidation to oxy-hydroxides such as hematite and goethite leaving vugs. Vugs pesudomorphous after pyrites are filling with uranium (14.6 % U) and xenotime –bearing solutions (33. % Y, 8.8 % P).

Fluorite (CaF_2) is common and confirmed by XRD and analyzed by ESEM .It contains 70.2 % Ca and 29.2 % F. Fluorite occurs as veinlets or disseminated grains, exhibiting colorless to pale green colors and associated with iron oxides. Apatite Ca $_5$(PO$_4$)$_3$(OH, F, Cl) is extremely variable. The intensity of the color increases with the increase in Mn-content of the apatite. The apatite contains 65.2 % Ca, 25.8 % P, 6.9 % Pb and 2.2 % Cl.

Pyrophyllite ($Al_2O_3.4SiO_3.H_2O$) is white to pale greenish color, low hardness, often translucent, pearly luster and crystallized in monoclinic system. It usually occurs as lamellar radial aggregate or as cryptoscaly compact rock. Pyrophyllite is a low temperature hydrothermal mineral and usually associated with quartz, carbonate and hematite. It contains 36.8 % Al_2O_3 and 63.2 % SiO_2. Chaistolite is common and occurs as veinlet or disseminated grains, chaistolite exhibits colorless to pale green colors. It is associated with opaques and contains 14.70 % Al_2O_3 and 85.30 % SiO_2.

LATERITES

Several samples were collected from some Natash laterite for mineralogical studies using physical dressing and XRD technique. The highly altered vesicular black basalt characterize mainly by oolitic – pisolitic (Fig.4a) textures , lack of graded – bedding , in addition to the presence of gypsum in erosional and above unconformity surfaces, suggest an authigenic origin(Grubb, 1971) for Natash laterite deposits. The domain of rounded quartz grains (Fig.4b) can be attributed to a long period of transportation and faraway source area.

Mineralogical results proved the presence of both kaolinite and montmorillonite as clay minerals. The abundance of clay minerals probably originate after feldspars' and or/ muscovite flacks. However, the large and thick'' horizon ''of laterites dominated by kaolinite can not be formed in semi-arid conditions, where Costa et al., (2009) recognized that, kaolinite formed by tropical weathering. The heavy minerals assembly is dominated by xenotime, fluorite, zircon, apatite, and allanite. Henderson (1996) believed that zircon, fluorite and xenotime are enriched in HREEs, apatite is enriched in middle REEs (MREES), while allanite is enriched in LREEs.

The presence of green hyperthene, diopside and tremolite indicates that, their main source can be alkali olivine basaltic and mugearites flows. Gypsum, hematite, goethite, calcite and ferropargasite are also recorded. Hematite is the source of the reddish brown spots and together with goethite constitutes the local crust. Gypsum is a typical mineral formed during the lateritization process and restricted to the upper part of the lateritic profile (Costa, 1991, 1997). In general, the presence of hematite, goethite, gypsum and the great abundance of kaolinite, indicates that the Natash laterites are related to tropical weathering (Costa, 2009).The presence of ilmenorutile and rutile in the laterites indicate reducing and low pH conditions during formation of laterite deposits (Ozlu, 1983) .

GEOCHEMISTRY

The whole rock major oxides and trace element geochemical data for eleven representative samples of Natash laterites are presented in (Table1). The REE distribution is well clarified in (Table 2).

The main controlling features are the Al_2O_3 (11.04 -12.45), Fe_2O_3 (9.18-16.37) and organic matters (L.O.I. ranges from 10.72 to 16.00) (Table 1). The higher contents of SiO_2 indicate the prevalence of quartz over kaolinite. According to Costa model (1991, 2007) ,the increase in Fe_2O_3, TiO_2 , Cr and Ni concentrations (Table 1) without the increase in the Al_2O_3 contents, may characterize the overprinting of the immature laterites at the base.

The trace element concentrations (Zn, Cu, Cr and Mn) are in general higher than the earth crust values, which confirm a basic flows derivation for weathering and therefore for laterite deposits. The Cr and Ni contents (Table 1) are positively correlated to Fe, and consequently to both hematite and goethite, the most important iron minerals found, which increased in concentration upward in the upper laterite profile (reddish brown color).

Based on the mineralogical classification of Aleva (1994), most of the studied Natash laterites fall within the kaolinite and bauxitic kaolinite fields (Fig.5a). Nevertheless, the ternary SiO_2 – Al_2O_3 – Fe_2O_3 plots (Fig.5b) indicate that the paleogeological conditions at Natash area favoured kaolinization and bauxitization over lateritization , due to moderate mobilization and less enrichment of aluminum compared with high SiO_2 (relatively stable relic mineral) and iron oxides.

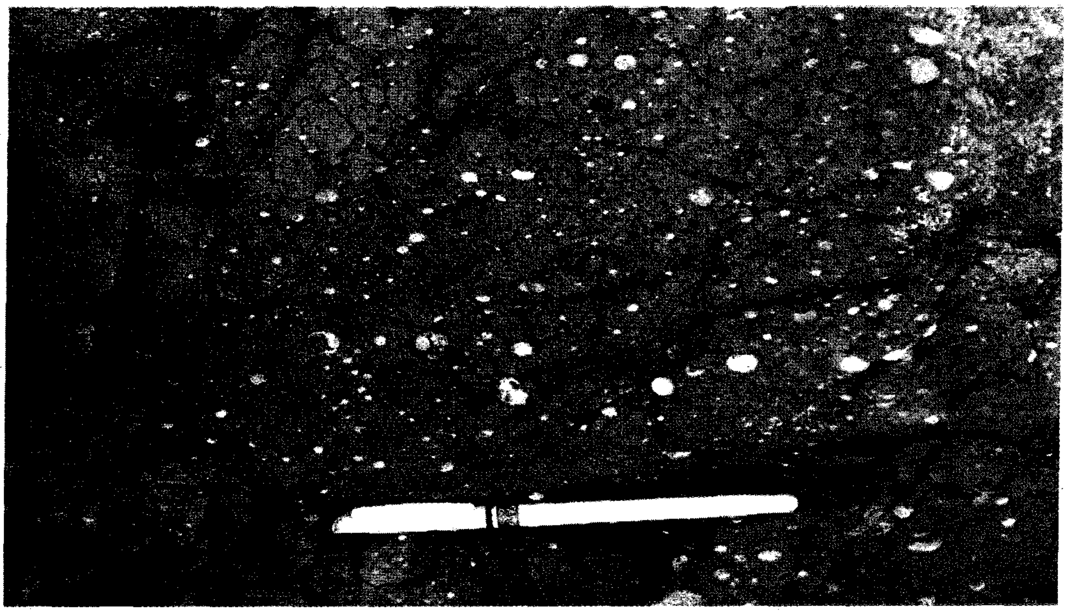


Fig.(4a).Close up view showing typical white oolitic- pisolitic textures in andesite –basalt.

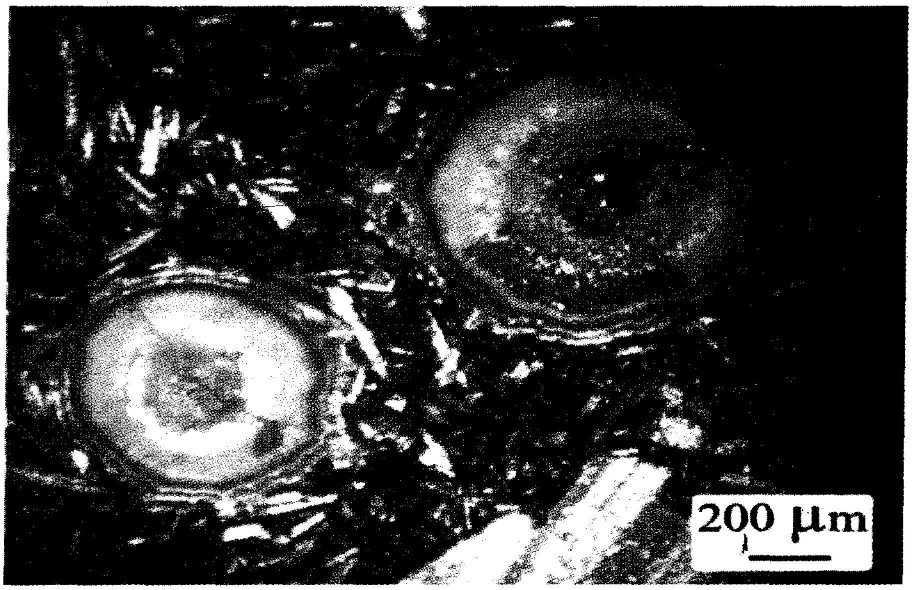


Fig. (4b):Photomicrograph showing oolitic texture filled with secondary quartz in Wadi Natash basaltic andesite.

RARE EARTH ELEMENTS

REE data for Natash laterite samples of variable colors (reddish -brown, light-grey and dark- grey) are represented in table (2) .The non- altered basalts and rhoylites(data from Mohamed, 2001) are depleted in REEs especially HREEs compared to the laterite samples. The REE contents in laterites (excluding Y) decrease from the dark- grey (5613 ppm) through the light- grey (4620 ppm) to the reddish brown laterites (2809 ppm). This indicates that the reddish-brown laterites are in relatively advanced state of weathering than the black laterites, and compatible with the REE contents that increase with the decrease of weathering (Boulange et al., 1996).The Yb ,Dy, Nd , Er, and Pr elements are higher in their content ,relative to the others REEs (Table 2).Enrichment in individual HREEs, such as Yb xenotime are exceptional (Buck et al., 1999) (in the present study) . Occasional high enrichments in Yb ,Dy and moderate in Gd are noticed in Natash laterites (Table 2).

All the Natash laterite samples are characterized by very steep REE with HREE enrichment (Fig. 6). The shape of the normalized REE pattern can be attributed to the minerals that constitute the rock as well as the processes that affected the rock formation. The REE concentration ranges from 3619 – 7143 ppm (from reddish- brown to dark-grey laterites respectively) with an average of

4974 ppm ,indicating that HREE were fractionated than LREE .The (Gd / Yb) ratio of Natash laterites (0.25) is less than 1, which suggests that ,these laterites were derived from the more HREE depleted source rocks.

The mafic rocks exhibit lower LREE / HREE ratios without any Eu anomalies (Cullers, 1994). The LREE is less concentrated than the HREE by a factor of 0.57 (LREE / HREE = 0.57) which suggests that, the REE contents in laterites were derived from the fractionation of basic and intermediate flows. Fractionation of the LREE relative to the HREE may be due to the presence of olivine, orthopyroxene and clinopyroxene, for the partition coefficients increase by an order of magnitude from La to Lu in these minerals. In basaltic and andesitic liquids, however, the REE are all incompatible in each of these minerals and are not slightly fractionated. Enrichment in the middle REE (MREE) relative to LREE and HRRE is chiefly controlled by fractionation of both hornblende and clinopyroxene (Buck et al., 1999).The LREE were mobilized more effectively than the HREE. The REE mobility is controlled by pH, high water/rock ratios and abundant complexing ions CO_3^{2-}, F^-, Cl^-, PO_4^{2-}, SO_4^{2-}, (Hass, et al., 1995).

The REE elements were extracted with recovery of 60 % from a technological laterite sample on a lab. scale, with a good results compatible with the present REEs analysis (Naser Abdel Aziz and Enas, El- Sheikh NMA, personal communication).

SUMMARY AND CONCLUSION

1-The present paper records for the first time the occurrence of laterites-bearing REEs in Natash volcanics, at the southeastern Desert of Egypt .The Natash volcanic rocks lie between the lower and upper Nubia sandstone, and are represented by Natash flows (alkali olivine basalt, basaltic- andesite, mugearites and benmoreites), volcaniclastic sediments (agglomerates, lapillistones & laminated tuffs) and less common trachytes and rhoylites.

2- Laterite overlies the Natash flows and covered by the volcaniclastic sediments. The REE contents in laterites (excluded Y) decrease from dark- grey (5613 ppm) through light- grey (4620 ppm) to reddish brown laterites (2809 ppm)at the top with an averaging thickness ranges from 5 to 15 m above Wadi level . The paleogeological conditions at Natash area favoured kaolinization and bauxitization over lateritization, due to moderate mobilization and mild enrichment in aluminum compared with high SiO2 and iron oxides.

3- The REE contents in laterites (excluding Y) decrease from dark- grey (5613 ppm) through light- grey (4620 ppm) to reddish brown laterites (2809 ppm).This indicates that the reddish-brown laterites represent a relatively advanced state of weathering than the dark-grey laterites, and compatible with the REE contents generally increased with decreased weathering. The LREE is less concentrated than the HREE by a factor of 0.57. (LREE / HREE = 0.57) which suggests that, the HREE contents in these laterites were derived from the fractional of basic and intermediate flows.

4-The barren nature of Natash laterites –bearing REEs from any radioactive elements, in addition of their high contents of REEs, must lead to future evaluating of the reserves of the leachable laterites –bearing REEs.

Table (1): Major oxides, trace element and total REEs composition of laterites from W. Natash volcanics.

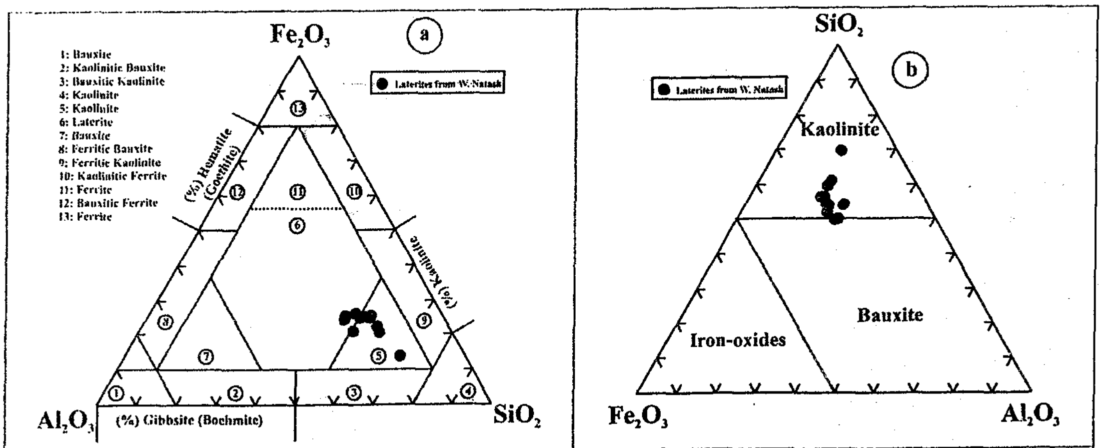
Major oxides	1	2	3	4	5	6	7	8	9	10	11
SiO_2	39.58	46.34	36.39	33.02	34.78	40.32	35.30	32.58	35.50	32.30	30.02
Al_2O_3	12.18	11.04	12.05	12.45	11.64	12.08	14.15	13.84	16.26	16.14	15.45
TiO_2	3.51	0.92	3.62	3.49	3.35	2.20	2.70	3.35	3.51	3.60	3.00
Fe_2O_3	14.78	9.18	16.37	15.18	15.18	13.58	16.29	16.38	13.58	16.40	15.67
CaO	8.40	8.40	8.40	9.80	9.80	5.60	7.40	8.60	9.60	8.40	9.50
MgO	5.00	5.00	6.00	5.00	5.00	4.00	7.00	5.00	5.31	6.00	5.30
Na_2O	3.71	2.70	4.05	3.37	1.74	3.78	3.05	1.84	3.50	4.04	3.30
K_2O	0.35	2.86	0.64	1.07	0.97	2.99	0.64	0.90	0.35	0.60	1.14
P_2O_5	1.17	0.16	1.23	1.10	1.25	0.40	1.24	1.00	1.10	1.27	1.14
L. O. I.	10.72	13.03	10.86	15.04	16.00	14.59	11.85	16.25	10.79	10.86	15.00
Total %	99.40	99.63	99.61	99.52	99.71	99.81	99.61	99.71	99.40	99.61	99.52
Trace elements											
Cr	149	37	163	29	163	132	92	67	22	63	100
Ni	43	27	45	13	43	49	45	40	14	36	34
Cu	29	24	25	24	31	28	30	29	24	27	34
Zn	69	68	77	146	91	67	106	94	115	68	93
Zr	218	499	219	462	31	226	253	230	538	202	190
Rb	15	44	37	46	16	27	19	25	29	24	24
Y	16	29	17	38	15	17	17	19	31	17	17
Ba	341	520	378	680	306	337	293	292	405	272	282
Pb	u.d	2	4	2	u.d	u.d	10	7	3	u.d	u.d
Sr	348	178	226	282	605	324	263	1016	252	346	324
Ga	17	28	21	29	21	20	21	22	25	18	20
V	219	58	304	134	353	229	254	309	56	270	342
Nb	14	37	12	33	16	14	16	16	40	13	14
REEs	5290	7420	6325	5480	6110	4215	3525	3345	4250	5730	3655

u.d=under detection limits

Table (2): Results of REEs and Y concentrations for representative samples from Natash laterites.

elements	1B	2G	3R	4**	5**
Y	1530	1282	810	34	129
La	230	190	115	47	141
Ce	0.00	0.00	0.00	98.10	486
Pr	455	370	225	12	31
Nd	722	580	355	49	116
Sm	371	300	180	10	27
Eu	324	270	170	2.4	2.70
Gd	288	240	140	7	29
Tb	421	360	215	0.9	4
Dy	821	670	420	6.8	22.9
Ho	393	310	193	0.92	4.2
Er	456	380	232	3.25	11.70
Yb	1132	950	564	2.6	10
REEs	5613	4620	2809	239.9	885.5
REE+Y	7143	5902	3619	273.9	1014.5
LREEs	2102	1710	1054	218.5	662.7
HREEs	3511	2900	1764	21.4	222.8
HREEs +Y	5041	4192	2574	55.47	210.8
LREEs /HREEs	0.61	0.58	0.54	10.2	2.97

1B, 2G & 3R represents dark-grey, light-grey and reddish brown laterites respectively.
4 = Natash olivine basalt and 5** = Natash rhoylites (from Mohamed, 2001)**



Figs. (5): a) plot of Natash laterite samples in a Fe_2O_3 – Al_2O_3 – SiO_2 ternary diagram after Aleva, (1994) and b) SiO_2 – Al_2O_3 – Fe_2O_3 ternary diagram after Mutakyahawa et al., (2003).

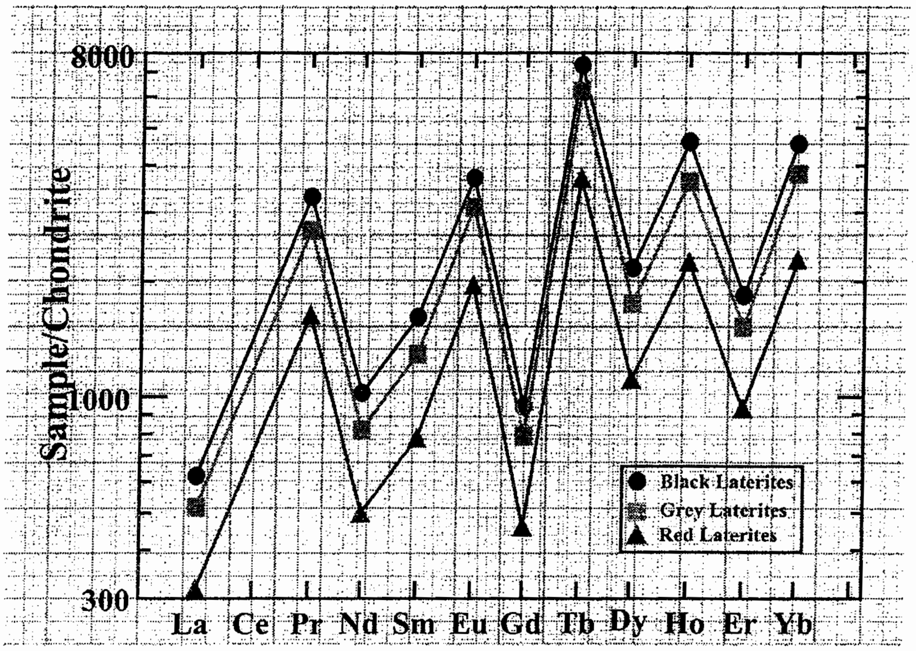


Fig. (6): REE distribution patterns for Natash laterites .The chondrite - normalized REE diagram after Taylor and McLennan (1985)

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