African superPlume is responsible for geology and hydrocarbons (HC) in Western Baluchestan, Middle East? New materials, "hot" tectonics, melt and fluid inclusions, problems, and constraints

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Abstract. **A satisfactory tectonic-magmatic-metallogenic correlation in the East Iran, Middle East for Alpine time was revealed in the region studied (metallogeny – led by outstanding regional trio: Drs. E. Romanko, A. Houshmand-Zadeh, and M.A.A. Nogole-Sadat). Geological northeastern (NE) zoning and "hot" tectonics due to the African superplume activity including probably slab delamination is revealed here too. Strongly dominated rocks of calc-alkaline and shoshonite series deal with a known subduction of Arabian plate beneath the Central Iran block. Intraplate African superplume-related rocks are subalkaline – alkaline ones including Quaternary carbonatites in Hanneshin, Afghanistan. Tectonic-magmatic pair could be postulated here. General oil / hydrocarbons (HC) productivity decreasing to the north could be in an agreement with corresponding decreasing of African superplume activity too. Regional economic Cu-Au etc. metallogeny is mainly stipulated by a subduction mentioned.**

Keywords. **Alpine-Himalayan conjunction, Baluchestan, Middle East, magmatism, tectonics, African superPlume, delamination, rock chemistry, mineralogy, metallogenic peculiarities, melt and fluid inclusions, northeastern (NE) tectonic-magmatic-metallogenic and oil – hydrocarbons (HC) zoning.**

It is good known that Middle East is geologically, economically… extremely important region, but, however, very irregular investigated. Great importance of its regional study is obvious. Metallogeny and geology of poorly studied East Iran close to the Alpine - Himalayan structures junction (Khain, 2001; Khain, Leonov, 1988; E. Romanko et al, 1984; Houshmandzadeh et al., 1986; Imamverdiyev, 2000; Stocklin et al., 1965; Milanovsky, Koronovsky, 1973 etc.) recently studied by us under the leadership of outstanding trio – known regional specialists Drs. E. Romanko, A. Houshmandzadeh, and M.A.A. Nogole-Sadat. We present new data on magmatic rocks of the region studied: dominated Paleocene – Quaternary subduction-related calc-alkaline rocks (first group) and principally other subordinate rocks younger (?) - Neogene – Quaternary (?) intraplate subalkaline and rarely - alkaline ones (second group).

Rocks of the first group (subduction-related differentiated calc-alkaline rocks: basalts - dominated andesites - rhyolites, granodiorites, etc.) are the products of a large subduction of the Tethys lithosphere and Arabian plate beneath the Central Iran block or microplate (Fig. 1). This process is confirmed by the regional tectonic analysis, tomography by known J. Ritsema's team (Bull et al., 2009 etc.) and petrology and geochemistry (Imamverdiyev, 2000; Romanko et al., 2012; etc., fig. 1). Catastrophic earthquakes of ca. 8 M and more on the Richter scale, unfortunately, are not rare here. A recent catastrophic example is the Bam earthquake in 2003.

Formation of the antipodes - intraplate K-Na midalkaline and alkaline rocks subordinate (including true carbonatites Afghanistan and Arabia), the second group rocks relate to the African superplume activuty (table 1, fig. 1). (Neogene lamproites of Algeria etc. - E. Romanko et al., 1988; Romanko et al., 2012; etc.). They are trachybasalts, hawaiites , basaltic trachyandesites, and trachyandesites on classification and discriminated digrams (fig.2) (Bogatikov et al., 1987; Luchitsky, 1985, Yarmolyuk et al., 2001 etc.).

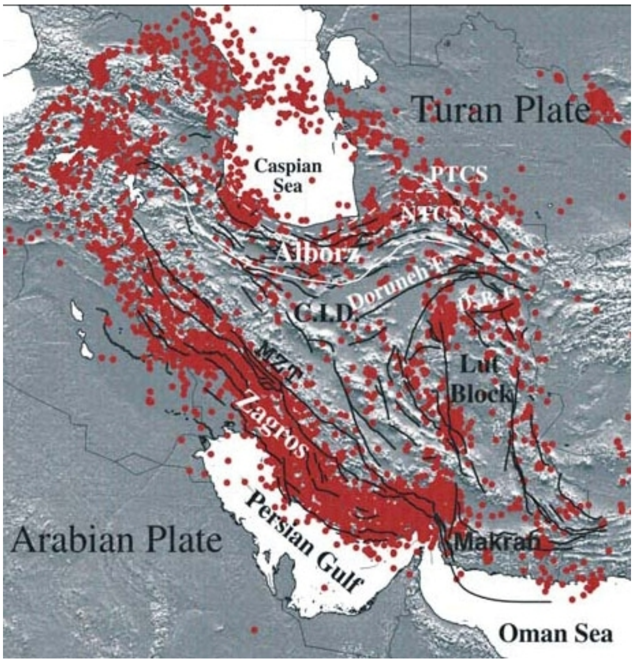

Fig. 1. Distribution of earthquake epicentres in the Middle East due to detailed work (Alinaghi et al., 2007). We can see known Lut Block and immediately next to the east studied East Iran mobile zone area (Khain, 2001, Hushmandzadeh et al., 1987, E. Romanko et al., 1984, etc.).

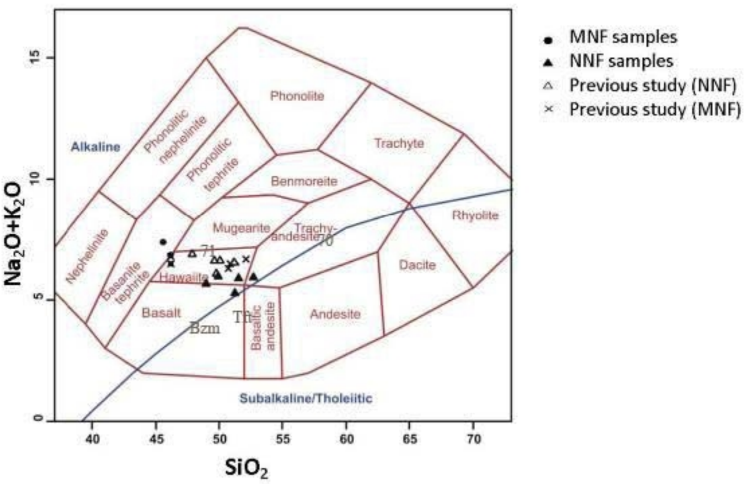

Fig.2. Total alkali, Na_2O+K_2O (wt %) versus SiO_2 (wt %) diagram for clasification of Middle East volcanic rocks (Cox et al. 1979). Tft – Taftan stratovolcano some average rocks, Bazm – Bazman stratovoclano some average rocks, 71 and 70 – intraplate rocks groups, Helmand (Afghan) block, using (Saadat S, Stern C.R., 2011).

These rocks, in contrast to the calc-alkaline, characterized by an enrichment of both large-ion lithophile elements (LILE) - K, Rb, Ba, and HFSE lithophile elements - Nb, Y, Ta, Zr, Ti, P, etc. (tab.1, fig. 3) with a characteristic high Eu/Eu* - more than 1.1. Increased concentration of P_2O_5 - sometimes more than 1.0% - is a characteristic feature of the second group of rocks.

We have received fair low isotopic data $^{87}Sr/^{86}Sr$ (ISr) in two samples of intraplate rocks of the second type - trachyandesites R70-2 – 0.7039 ÷ 0,2 (high K/Rb=393) and trachybasalt R71-4 –

0.70489 ÷ 0,18 (K/Rb=375, fig. 4). For subduction-related calc-alkaline andesite of stratovolcano Bazman, sample R25 was determined a rather low value ISr = 0.70456 ÷ 0.05, K/Rb=250 (tab. 1). Isotopic data of these our intraplate rocks differ from collisional and subduction-related rocks from Anatolia, Turkey (Dilek et al, 2010; Khain, 2001; Imamverdiyev, 2008 etc.). Igneous rocks of the volcanic rocks are fully differentiated series of the regional known Sahand – Bazman belt. Known stratovolcanoes in this belt are: Bazman with a height 3490m and Taftan 3940m (old mark was 4042m). Old 0.7049 isotopic date for a ‘volcanite’ of an unnamed volcano in a desert was reported by Camp and Griffis in 1982 (Camp, Griffis, 1982).

Table 1

Major and trace-element composition of Middle East volcanic rocks

Sample	1	2	3	4	5	6	7	8	9
SiO_2	48.17	57.80	54.50	54.00	60.69	65.39	65.10	85.00	58.67
TiO_2	2.20	1.31	1.87	1.52	0.36	0.42	0.51	0.60	1.70
Al_2O_3	3.80	17.48	15.94	-	15.32	13.71	15.54	4.00	15.13
Fe_2O_3	9.32	4.37	6.39	6.25	2.70	3.25	2.42	3.21	6.69
FeO	2.56	1.07	0.40	-	2.07	-	2.32	1.10	2.19
MnO	0.14	0.09	0.09	0.08	0.09	0.057	0.13	0.02	0.09
MgO	5.75	2.27	3.37	-	3.65	1.39	1.72	0.52	2.28
CaO	8.98	7.10	7.58	7.40	3.90	2.08	2.80	0.29	1.77
Na_2O	4.93	5.11	5.81	-	3.64	2.87	3.36	0.28	5.06
K_2O	1.31	1.42	1.73	1.09	4.38	4.51	4.59	0.21	2.05
P_2O_5	0.23	0.61	1.05	-	0.31	0.11	0.20	0.09	0.30
Rb	30	19	20	15	145	117	109	7	47
Ba	375	293	-	292	1230	577	1597	390	557
Sr	1185	912	4470	950	870	232	359	440	263
Ni	86	53	58	59	50	7	13	10	44
Co	33	14	-	-	12	5	6	4	21
Cr	64	60	38	/_64	50	16	18	11	72
V	220	95	-	-	81	63	54	55	107
Cu	63	65	64	77	69	15	11	17	33
Zn	113	88	113	98	32	40	57	8	82
Pb	5	20	51	5	20	27	22	20	10
Zr	283	232	339	217	96	158	246	136	219
Y	25	19.5	25	15	15	11	29	13	23
Nb	23	17	19	-	5.8	8	12	6	30
Sc	19	10.7	-	26.2	10	-	-	6.5	10
Th	3	3.65	-	4.84	12	-	16.7	1	12
U	1.2	0.99	-	1.31	1	-	4.62	3	3
La	44	32.4	-	30	18	-	34.0	15	35.2
Ce	101	68.3	-	63	32	-	64.5	28	64.2
Nd	-	31.4	-	-	-	-	27	-	25.0
Sm	-	6.00	-	-	-	-	5.6	-	5.1
Eu	-	2.11	-	-	-	-	1.3	-	1.9
Gd	-	5.08	-	-	-	-	4.1	-	4.8
Tb	-	0.78	-	-	-	-	-	-	0.9
Er	-	1.64	-	-	-	-	1.9	-	1.6
Yb	-	1.26	-	-	-	-	1.7	-	1.6
K/Rb	560	620	586	581	245	307	350	230	350

1 and 2 - trachybasalt (sample R71-4) and trachyandesite (sample R70-2) correspondently, Haji lake, Neogene (?), Afghan block, 3 - trachyandesite, Baluchestan, Iran (Camp, Griffis, 1982), 4 - trachyandesite, R75wp, Lut block, 5 - syenite, Lar intrusiion with Cu-Au mineralization, Miocene(?) 6 – K-dacite, R75, Lut block, and 7 - trahydacite, standard, Kurama Ridge Middle Tien Shan, Karamazar, Tajikistan, Late Carboniferous - Early Permian, using data and extrapolation from (Rusinov, Kovalenker, 1991; Razdolina, Moralev et al., 1993; Mamajanov, 2005; Romanko et al., 1990) 8 - leucorhyolite, R82, east Bazman volcano, Quarternary(?), 9 - trachyandesite, continental rift, standard, Proterozoic, Pechenga area, Fennoscandian or Baltic shield, Romanko et al., 1989.

Table 2

Chemistry of melt inclusions glass (wt %) in plagioclase (1, 3), host mineral (2, 4), host acid K-volcanite (5), leucorhyolite from Bazman stratovolcano, and plagoclase standards (7-9) due to A. Betekhtin, 1953.

sample	SiO_2	TiO_2	Al_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	Cl	S	Sum
1	74.77	0.19	12.94	0.58	0.08	0.12	1.52	3.88	3.93	0.26	0.00	0.01	98.28
2	58.69	0.01	24.77	0.23	0.00	0.01	6.68	7.22	0.49	0.00	0.00	0.01	98.11
3	74.48	0.15	14.53	0.53	0.04	0.10	1.69	3.02	4.10	0.00	0.01	0.01	98.66
4	58.36	0.00	24.71	0.28	0.02	0.05	7.15	6.90	0.46	0.04	0.00	0.01	97.98
5	65.39	0.42	13.71	2.93	0.06	1.39	2.08	2.87	4.51	0.11	-	-	-
6	77.00	0.60	13.00	3.98	0.02	0.52	0.29	0.28	0.21	0.09	-		-
7	58.16	-	26.57	-	-	-	8.35	6.92	-	-	-		-
8	56.05	-	28.01	-	-	-	10.1	5.89	-	-	-		
9	62.43	-	23.70	-	-	-	5.03	8.84	-	-	-		

1, 3 - melt inclusions glasses in plagioclase, 2, 4 - host minerals, 5 – host K-volcanite, 6 – leucorhyolite from stratovolcano Bazman, Quaternary(?), 7-9 plagioclase standards: 7 - andesite, SiO_2 = 58.16, empirical formula - $Na_{0.6}Ca_{0.4}Al_{1.4}Si_{2.6}O_8$, chemical formula andesite - (Na, Ca) $(Si, Al)_4O_8$, Webmineral.com, 8 - 9 - plagioclase theoretical composition: An_{50} (8) and An_{25} (9), by A. Betekhtin, Moscow, 1953.

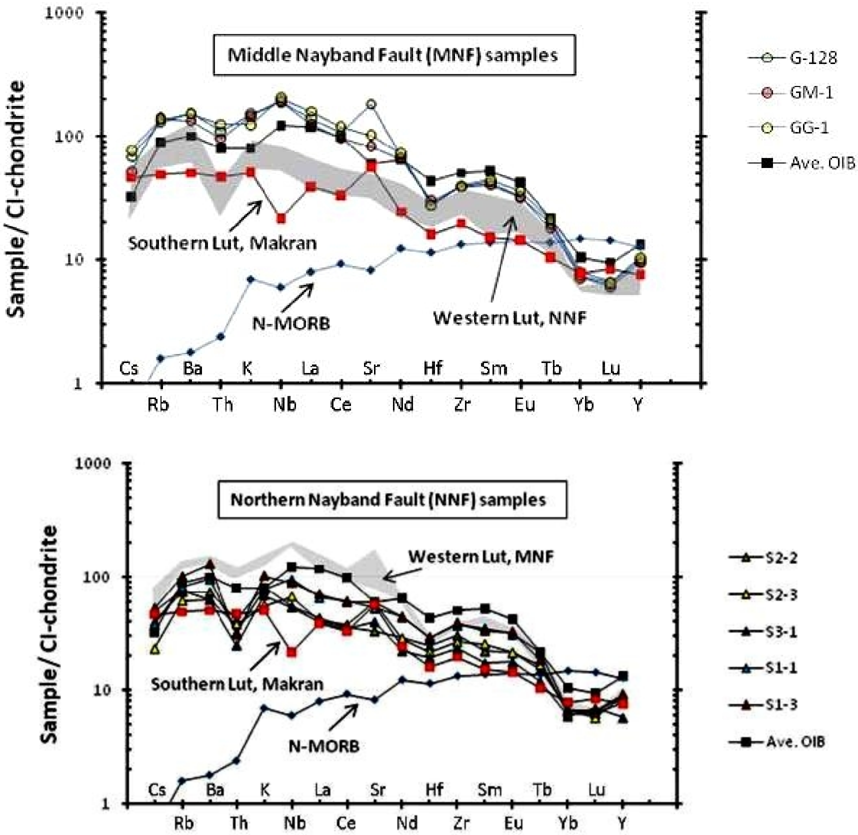

Fig.3. The distribution of the contents of rare and trace elements normalized to chondrite composition (Sun, McDonaugh, 1989), using (Saadat S, Stern C.R., 2011).

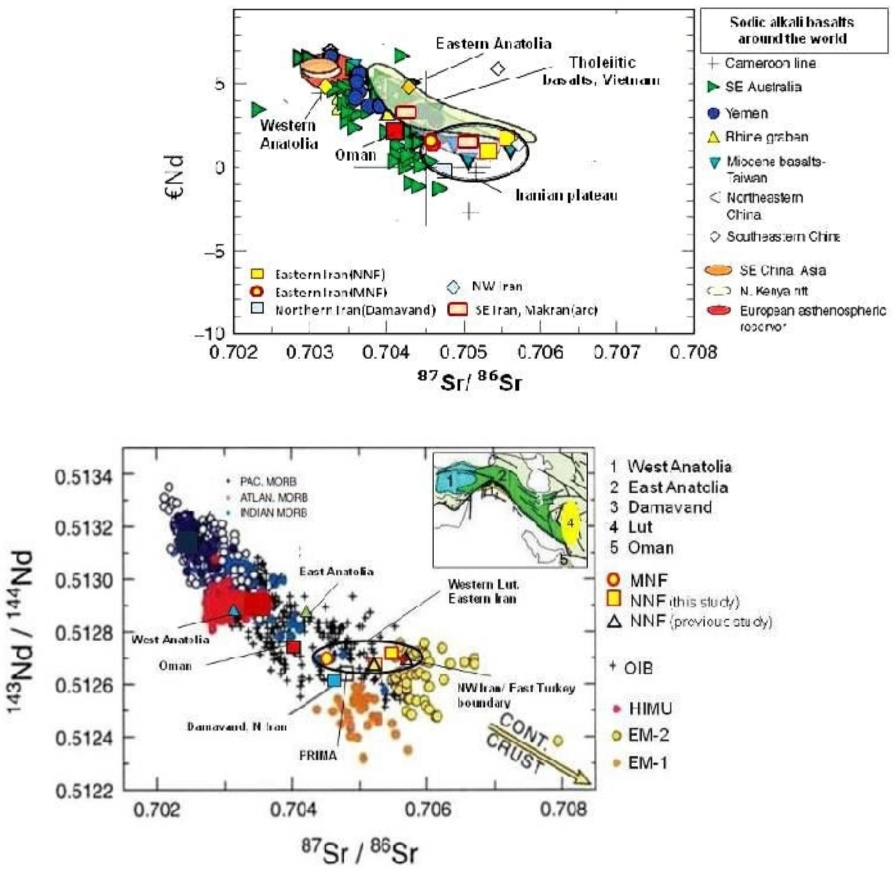

Fig. 4. Isotope systematics of igneous rocks in the region and standards using (Saadat S, Stern C.R., 2011).

Melt inclusions (as well as fluid ones – by Dr E. Romanko et al., 2000) were maybe firstly investigated in this area under the leadership of Dr. Prokofiev in the region studied. Some conclusions on this study are:

- Melt inclusions are not typical for the African super-plume-related intraplate igneous rocks due to tomography by known Ritsema's team (Bull et al., 2009 etc).

- unusual fairly high temperature, 1150-1180º C - up to 1220º C melt inclusions were revealed in plagioclase of subduction-related K-dacite, sample 75-l by V. Prokofiev et al, 2011 (Prokofiev, 2000; Romanko et al., 2012, Fig. 5 and 6, Table 2.). This fairly deep, non-calc-alkaline rock was also affected by indirect (?) influence of a huge African super-plume, as proposed. Homogenization occurs under High T = 1150-1220º C (for comparing, for example, T much lower for acid volcanite of Quaternary Pektusan volcano, Korea, presentation of Andreeva et al., IGEM, RAS, Moscow, 2013). A higher viscosity of a glass provides more inclusions coexistence in a sample.

Maximal concentration on fluid CH_4 and other CH-based fluid inclusions were revealed in shallow intrusions on the contact with carbonate-rich host rocks in west Taftan zone; also in important Lar syenite massif with Cu-Au (E. Romanko et al., 2000; Romanko et al, 2012, in Russian). Minimal data are in Cretaceous ophiolitic mainly melange rocks.

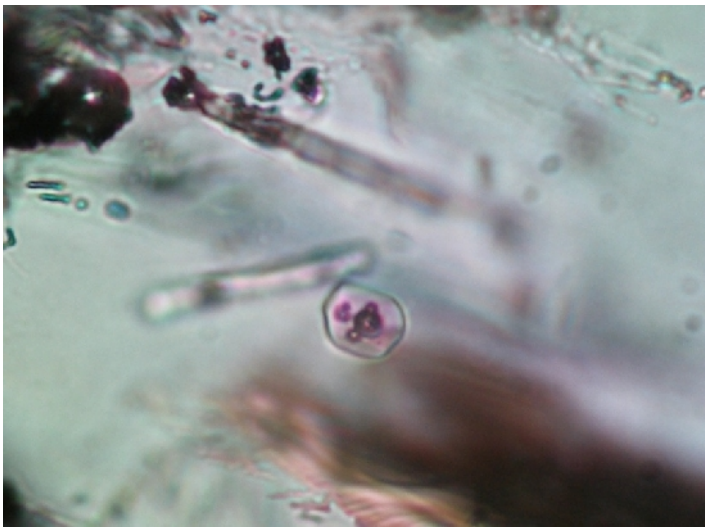

Fig.5. T=1150°C. View of melt inclusions in acid glass from plagioclase

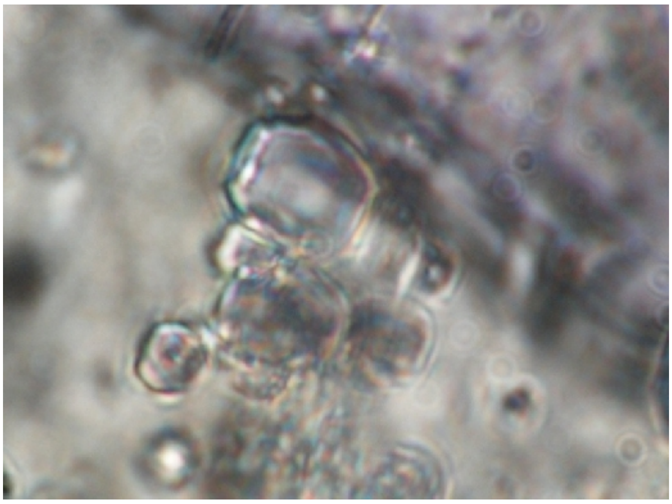

Fig. 6. T=1220°C. Homogenization.

Second group rocks are from deeper mantle source versus those of the first group. This is supported by the following:

- Geological and petrographic and mineralogical data;
- The general style of petrology and geochemistry of these rocks, the rocks are not contrary to other regions, plume-related magmatism;
- Demonstration geochemical relationships, for example, the stable high K/Rb = 560-586-620.

The region is expected to at least partial compensation for the pre-emptive tectonic compression (with display calc-alkaline magmatism) – stretching from the corresponding intraplate magmatism. The latter, according to the imaging may be associated with the tail of the most powerful African superplume [2 and others]. Perhaps, there is also discussion in modeling - the partial screening of the plume push up plate, which is not an obstacle - it is known that the plate moves up does not stop the movement of the tail superplume laterally, as perhaps in this case.

Metallogenic questions

Calc-alkaline intrusive, extrusive, pyroclastic and volcanogenic-sedimentary rocks of the first group are characterized by a common copper-gold metallogenic profile for the province, matching belt metallogeny mentioned Sahand - Bazman whole country. The overwhelming majority of occurrences the study area is associated with magmatic complexes. Dr. Eugene Romanko has revealed such metallogenic types here as:

- Multi-sulfide (Au-Mo-Cu-Pb-Zn) subvolcanic porphyry type;
- Au-As-Hg-W-Mo-volcanic exhalation one;
-Low-sulfide gold-silver plutonic one;
-Gold-copper (Au-Cu) skarn and plutonic-hydrothermal one (E. Romanko et al., 2000) using also known data on other mineralization (Prokofiev et al., 2000; Vikentiev et al., 2004 etc.);
-Sulfide, sulfur, alunite exhalation, surface one;
-Native-copper-sulphide volcanogenic one with zeolites;
-Silver volcanogenic sulphide (+ gold?) one.

Thus, intraplate rocks are strongly specialized in REE, P (usual process), then in Sr, Ba, U, Th due to nowdays materilas. So, tectonic-magmatic, and as revealed E.Romanko – metallogenic zonation in the region was revealed in the region studied (at least in the Central – East Iran). Younger magmatic products are in the northeast of region due to lithosphere subduction and decreasing of Afrocan superplume activity in the same direction. Subduction-related (1 group of rocks) dominated calc-alkaline rocks and shoshonites-latites. , and, intraplate African superplume-related (Laverov et al., 2004; Yarmolyuk, personal communication, 2012, etc.) midalkaline – alkaline rocks including known Pleistocene carbonatites of Hanneshin, Afghanistan and, also, of one of Arabia are subordinated (2 group of rocks). Rocks of 1 and 2 groups are interpreted by us as a tectonic-magmatic couple due to one from physics etc. In this case, at least, partial compensation of subduction compression by the intraplate extension is possible. The presence of the mentioned Cenozoic intraplate carbonatite-derived depth of the melt - an argument in favor of the African superplume influence on the magma plume of a large region, which is in agreement with effective tomography of the well-known J. Ritsema's team (Bull et al., 2009). Also, There are materials about of oil/HC productivity decreasing in the direction mentioned as stressed known V. Khain with co-authors in the Explanatory map of Caspian Sea region scale 2: 2 500 000, from the extremely rich Persian Gulf to South – Middle – North Caspian Sea region, which in agreement with the increasing distance from the African superplume, within the known hydrocarbon belt as noted by a famous tectonist V. Khain (Khain, 2001 etc.; Romanko et al., 2012; etc.). More specifically, this HC global (?) belt is the Persian Gulf – Russian Arctic coast one due to old Russian maps, ex, USSR oil structures map scale 1:2 500 000 etc. HC productivity decreasing is in agreement with the increasing distance from the African superplume as seen by a tomography mentioned above. Also, salt domes are oriented due to northeast direction with respect to African superplume in the east Persian Gulf. More HC data needed, surely.

Conclusions

1. Northeast tectonic-magmatic zonation and partly – metallogenic one (last one by E. Romanko) in the region studied was revealed. It caused maybe directly by known Arabian plate subduction under the Central Iran. But African superplume controls magmatism, hot regional tectonic regime, and maybe even all geology including Jurassic Karoo flood basalts event, then Paleogene magmatism in the East Africa and Paleogene subduction, 11-9 Ma opening of Red Sea etc., maybe delamination of a slab in East Mediterranean (Khain, 2001; Imamvediyev, 2007, Romanko et al., 2012 etc.).

2. Two different types of Cenozoic magmatic rocks (antipodes) were revealed. Dominated Oligocene-Recent calc-alkaline and midalkaline - alkaline Neogene-Quaternary ones. First, the

calc-alkaline subduction geodynamic setting are responsible, and second - intraplate. Energetically favorable tectonic-magmatic pair with these types of rocks exists. Igneous rocks of the second group are generated deeper in comparison with the first group rocks, although sudden high/very high (?) temperature on melt inclusions in High-K subduction-related rocks were firstly received by known specialist V.Prokofiev (Prokofiev, 2000; Prokofiev et al., 2007, Romanko et al., 2012).

3. Calc-alkaline rocks are characterized by an economic copper-gold+-silver (Cu-Au+-Ag) regional subduction-related mineralization with a subordinate different mineralization (Au-Ag low-sulphide, Ag-sulfide with Au (?) etc.). Intraplate rocks bear REE, P, also Sr, Ba, Th, and U mineralization due to our data.

4. Deep processes - versus upper crustal ones - mainly control magmatism, tectonics and then metallogeny in the region studied. Hot tectonic regional regime is controlled mainly by African suprplume activity. Paleogene (Pg) Cu-Au regional mineralization is in a good agreement with a regional subduction.

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Tables 3-7 =

Table 3. Sum of gases by thermobarogeochemistry (cub. cm / kg)

Sample	Sum of gases Cubic cm/kg	Rock, age, notes
1. R26	0.933	subvolcanites and shallow intrusions, West Taftan volcano, diorites, probably Miocene
2. R38	1.022	Lar intrusion, Oligocene-Miocene
3. R61	0.401	ophiolites, Cretaceous
4. R85	0.655	ophiolites, Cretaceous
5. R35	**12.942**	Subvolcanites intruding CARBONATIC rocks, West Taftan stratovolcano, maximal contain, probably Oligocene-Miocene
6. R66	1.262	Young Cu-Zn-Pb mineralization with Au and Ag, Taftan stratovolcano, probably Quaternary

Sum of gases includes H_2, O_2, N_2, CO_2, CH_4, C_2H_6, C_3H_8, C_4H_{10}, C_5H_{12}, and C_6H_{14}. Temperature of Au mineralization is 220 – 278oC, Oligocene-Quaternary, important Lar intrusive massif with Au up to 25.4 ppm, T = 220–226oC by analyst R. Mudrogova, VNIIYG GB or Nuclear geophysics Institute, Moscow region (E. Romanko et al., 2000). Maximum of gases are in subvolcanites intruding CARBONATIC rocks. Minimum of gases are in ophiolite mélange rocks.

Table 4. $^{87}Sr/^{86}Sr$ (ISr) isotopic data from the rocks

Sample	$^{87}Sr/^{86}Sr$	Rock, mineral, age, notes
1.	0,7039+-0,0002	trachyandesite, sample R70-2, Hilmand (Afghan) block, maybe Neogene
2.	0,70489+-0,00018	trachybasalt, R71-4, lake Haji area, Hilmand (Afghan) block, maybe Neogene
3.	0,70456+-0,00005	calk-alkaline basic andesite, R25-1, East Bazman volcano, Neogene-Quaternary

4.	**0,7049**	**'volcanite' by Camp and Griffis, 1982, No data about age**
5.	**0,7047+-0,0003**	**biotite from trachybasalt, sample 64, Shurab - Galecha, Eocene**
6.	**0,7048+-0,0003**	**dacite, sample 166, Eocene**
7.	**0,7051**	**andesite, sample 206, Eocene**
8.	**0,7055**	**biotite from andesite, sample 203, Cheh-meh-Huri, Eocene**
9.	**0,7059**	**andesite, sample 193-A, no age**
10.	**0,7051**	**biotite from dacite, sample 143, Gazu area, no age**
11.	**0,7043**	**granodiorite, sample 146, no age**
12.	**0,7045**	**granodiorite, sample 151, no age**
13.	**0,7051+-0.0003**	**biotite from granodiorite, Gazu area, Campanian**

14.	**0,7048+-0,0003**	**biotite from dacite, Shurab-Galecha, Eocene**
15.	**0,7056+-0.0002**	**plagioclase from dacite, Eocene**
16.	**0,7065+-0.0003**	**biotite from dacite, Kuh-Berg, Eocene**
17.	**0,7070+-0.0003**	**granodiorite, Sor-Kuh, Middle Jurassic**
18.	**0,7041+-0.0001**	**Late Cenozoic magma, ENd= +4.1 +- 0.2, Great Caucasus**
19.	**0,7040**	**Late Cenozoic magma, ENd= +3, Great Caucasus**

1-3 - author's data, 4 - after (Camp, Griffis, 1982), 5-9 – Lut block, immediately west from East Iranian zone, after Sandwall E., Turkell N. Zor E. et al., 2003; 18-19 – Geat Caucasus, courtesy of I. Chernyshev, S. Bubnov, A. Lebedev et al., IGEM, RAS, Moscow.

Table 5. Composition of rock-forming and accessory minerals

Sample	1	2	3	4	5	6	7	8	9	10	11	12	13
SiO_2	55.45	54.11	55.20	43.79	44.65	46.25	46.87	53.86	54.54	64.49	68.94	68.61	0.018
TiO_2	0.26	0.19	0.22	1.88	1.71	1.84	1.36	-	-	0.26	-	0.13	29.79
Al_2O_3	1.51	1.52	1.50	11.37	7.88	7.69	6.40	29.51	28.22	17.82	17.20	17.85	0.02
Fe_2O_3	-	-	-	-	-	-	-	-	-	-	-	-	-
FeO	11.66	15.73	12.7	13.68	13.05	13.39	15.00	-	-	2.79	1.12	0.96	62.11
MnO	0.24	0.34	0.28	0.28	0.27	0.24	0.03	-	-	0.16	-	-	0.17
MgO	28.21	27.01	28.14	15.16	14.23	15.32	13.68	-	-	0.85	0.15	0.15	1.60
CaO	1.89	1.16	1.93	10.55	10.48	10.42	11.51	8.97	9.99	1.87	0.47	0.70	0.08
Na_2O	0.32	-	-	2.08	1.31	1.48	1.40	5.55	5.59	9.90	7.09	7.55	-
K_2O	-	-	-	0.49	0.38	0.44	0.75	0.28	0.34	1.78	4.96	3.71	-
P_2O_5	0.18	-	-	-	-	-	-	-	-	-	0.22	0.22	-

1-3 – Orthopyroxenes, 2-3 – standard bronzites, orthopyroxenes, 2 – from andesite and 3 – from Hb-norite, by H. Kuno,1964; 4-7 – amphiboles; 8-9 – plagioclases; 10-12 – alkali feldspars; 13 – magnetite.

Table 6. Major elements composition in the rocks

Sample	1	2	3	4	5	6	7	8	9	10	11	12	13
SiO_2	48.17	49.0	52.76	54.50	56.95	57.80	35.10	44.26	46.10	56.7	60.69	61.79	76.01
TiO_2	2.20	1.69	1.11	1.87	1.27	1.31	0.74	0.81	0.49	0.60	0.36	0.52	0.60
Al_2O_3	13.80	14.1	17.44	15.94	16.40	17.48	13.48	12.70	10.30	11.1	15.32	17.10	12.50
Fe_2O_3	9.32	9.10	3.14	6.39	5.28	4.37	7.53	4.81	5.10	4.90	2.70	1.16	2.51
FeO	2.56	-	5.40	0.40	0.46	1.07	0.73	0.87	-	-	2.07	3.53	1.21
MnO	0.14	0.11	0.13	0.09	0.08	0.09	0.16	0.12	0.08	0.10	0.09	0.10	0.02
MgO	5.73	9.23	5.55	3.37	3.35	2.27	5.46	6.60	9.00	4.85	3.65	3.04	0.37
CaO	8.98	7.72	8.62	7.58	6.80	7.10	26.66	17.10	15.86	12.0	3.90	5.25	1.55
Na_2O	4.93	3.06	3.46	5.81	5.33	5.11	0.80	2.96	0.86	1.84	3.64	4.11	0.28
K_2O	1.31	1.84	1.31	1.73	1.50	1.42	0.10	0.42	2.36	1.95	4.38	1.58	0.21
P_2O_5	1.11	0.40	0.40	0.51	0.59	1.05	0.16	0.38	0.12	0.12	0.31	0.19	0.03

1-10 – Hilmand (Afghan) block: 1-3 – trachybasalts, 11 – syenite, Lar massif, 12 – 13 – Bazman volcano, Neogene – Quaternary, author's data; 2, 7,10 – data by A. Houshmandzadeh and M.A.A. Nogol Sadat et al., 3 and 4 – (Camp, Griffis, 1982), '–' symbol means - not determined.

Table 7 Rare Earth Elements (REE) in the rocks studied and standards

Sample	1	2	3	4	5	6	7	8	9
La	32.4	32.1	44.8	18.6	35.2	34	63	78	31.3
Ce	68.3	69.3	91.9	37.7	64.2	71	115	50	50.8
Pr	8.23	8.05	9.80	4.32	-	-	-	-	-
Nd	31.4	32.9	37.8	17.7	25.0	43	70	63	21.3
Sm	6.00	5.98	7.24	3.92	5.1	10	17	12	4.09
Eu	2.11	1.83	1.31	1.23	1.9	3.0	4.5	4.0	1.26
Gd	5.08	5.55	6.19	4.20	4.8	7.5	11	10	3.42
Tb	0.78	0.71	0.70	0.54	-	-	-	-	0.55
Dy	3.20	3.13	3.76	3.50	-	-	-	-	-
Ho	0.68	0.57	0.64	0.69	-	-	-	-	-
Er	1.26	1.40	1.93	2.21	1.6	2.8	3.7	2.9	1.79
Tm	0.31	0.26	0.26	0.32	-	-	-	-	-
Yb	1.26	1.10	1.74	2.23	1.6	1.8	2.4	2.8	1.94
Lu	0.34	0.23	0.25	0.34	-	-	-	-	-

1-4 - intraplate rocks in West Baluchestan: 1-2 – trachyandesites, Neogene (r70-2 and r70-23 samples, analytics by A. Housmandzadeh and M.A.A. Nogol Sadat support); Helmand basin, 3-4 – subalkaline rocks, Lut block (r75-1 and r75-2); 1-4 - analytics by A. Housmandzadeh and M.A.A. Nogol Sadat support; 5-trachyandesite, standard, continental rift, Paleoproterozoic, Kuetsjarvi unit, Pechenga zone, Fennoscandian Shield by A. Romanko et al.; 6-8 – basalt and dolerite (intraplate standard rocks), continental rift, Jurassic, Karoo formation, Save-Limpopo rift, Zimbabwe, E. and A. Romanko; 9 – trachyandesite, Eocene, subduction-related setting, sample BH-13 from a well, Talmessi deposit, Central Iran, courtesy of H. Bagheri.