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PETROLOGIC MECHANISMS OF ORIGINATION OF PYRITE-BEARING HYDROTHERMAL SYSTEMS

(Figs. 4, Tabs. 3,)

Abstract: The petrologic aspects of the connection of base metal massive sulphide deposits with volcanic formations are considered. It is shown that the main cause of pyrite-bearing systems origination is the removal of fluid phases from basaltic melts, differentiating during ascending migration. In different geotectonic environment such a differentation proceeds differently, resulting in different mechanisms of fluid phase removal from primary magmas. Irrespective of concrete petrologic mechanisms of origination the postmagmatic pyrite-bearing hydrothermal systems would be characterized by sodium chloride trend and acid composition.

Резюме: В настоящей статье рассматриваются петрологические аспекты связы простых металлов крупных сульфидных месторождений и вулканических формаций. Отмечается, что главной причиной образования систем содержащих пирит является удаление жидких фаз от базальтовых расплавов дифференцированных во время восходящей миграции. В разной геотектонической среде такая дифференциация происходит по-разному и ее результатом являются разные механизмы удаления жидкой фазы от первичных магм. Независимо от конкретных петрологических механизмов образования, постмагматические гидротермальные системы содержащие пирит будут характеризованы тенденцией хлористого натрия и кислотным составом.

Introduction

Three ideas on the genesis of pyrite-bearing hydrothermal systems could be considered. The new poplar conreption suggests as a source of ore-forming solutions sea-waters heated at a depth by ascending plumes of tholeiitic magmas (Heaton — Sheppard, 1977; Spooner, 1980). Such waters, however, are commonly mixed with the magmatic ones (Hatori — Sakai, 1979; Graf, 1977; Humphis — Thompson, 1976). Fig. 1 represents all known available data on hydrogen and oxygen isotopes in fluid inclusions of different pyritic deposits. It is clearly shown that all fluids contain a mixture of jouvenile waters.

Quite different theory was forwarded by a number of Soviet geologists (Korzhinsky, 1976; Kutijev — Sharapov, 1979; Naboko, 1974; Ovchinnikov, 1973) which suggested that the origin of volcanic hydrothermal systems is related to intratelluric (transmagmatic) fluids, participating in the dynamics of surface waters. However, this process of the mantle degazation, or "the Earth's deep breathe" (Vernadsky), explaining very well a genesis of many endogenic deposits, is anable to describe a range of petrologic problems of base metal sulphides, for instance, peculiarities of petrochemistry of pyrite bearing volcanic series.

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The third scientific trend developed from the good old times (Lindgren, 1919), implies the magmatic source of ore-bearing fluids. But the connection between ores and magmatic ores is often very simplified resulting in considerable errors. So, Brunch (1976), Colly (1976) and a number of other geologistsconsider porphyry copper deposits as roots of base metal sulphides. These ideas were severaly criticized by Sillitoe (1980), which have correctly noted quite different petrologic properties of pyritebearing and "porphyry-bearing" primary magmas.

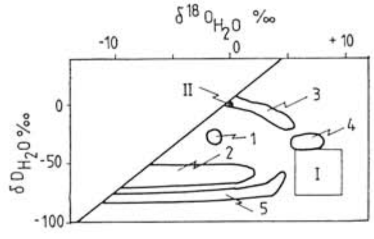

Fig. 1. Hydrogen and oxygen isotope composition of pyrite-bearing fluid systems.
Ore deposits: 1-2 — Kuroko: 1 — stratiform, 2 — veined (Hatori, Sakai, 1979); 3 — of Troodos complex, Cyprus (Heton, Sheppard, 1977); 4 — Ducktown, Tennessee, USA (Addi Sumit Kumar, Ypma, 1977); 5 — Madneuli, Lesser Caucasus. I magmatic waters; II - SMOW.

Ore-bearing criteria of magmatic affinities

Due to Soviet geologists investigations (Smirnov, Dzotsenidze, and Kotlyar, 1974; Borodayevskaya et al., 1974; Tvalchrelidze, 1981; Frolova et al., 1974) it was determined a close connection of base metal massive sulphide deposits with their hosted volcanic complexes. In these publications the eugeosyncline spilite-keratophire volcanism is divided into weakly differentiated basalt-andesite-basalt formation and pyrite-bearing bimodal basalt-rhyolite and basalt-andesite-dacide-rhyolite formations. Recent materials on pyritic deposits formation types indicate, however, that, not all types of base metal sulphides are related to differentiated volcanic complexes (Tab. 1). Cyprus-type and Fylys-chai-type deposits, for instance, lie at the top of undifferentiated tholeiiting feasure lavas.

In the other words, as the relation of base metal sulphide mineralization to basaltoid magmatism is proved by a vast number of geologic facts, there would exist petrologic criteria which should distinguish ore-bearing basaltoid affinities from "ore free" series of the same composition. And such reguliarities should be contrast in differentiated and undifferentiated magmatic formations. Taking a priori into account these theoretic thesis we have tried to summarize the petrologic data on pyrite-bearing volcanic complexes of the Caucasus (Tabs. 2 and 3).

The differentiated basaltoid pyrite-bearing formations originate in primary and secondary eugeosyncline belts. The first one have tholeiitic trend and are characterized by bimodal differentiation, the latter ones belong to calc-alkaline series with antidrome or homodrome differentiation types.

Despite of these base petrologic differences, the ore-bearing formations of considered type are characterized (Tabs. 2 and 3) by a range of common petrologic features. They are as follows:

Table 1

Systematics of base metal massive sulphide deposits

Type of deposits	Cyprus-type	Urals-type	Kuroko-type	Fylyz-chaitype
Composition	Cu-pyritic	Cu-Zn-pyritic	pyrite-barite-polymetallic	pyrite-polymetallic
Pb:Zn:Cu	1:10:50	2:10:25	1:3:1	0.3:9:1
Geotecto-tectonic position	ophiolitic belts	primary eugeosyncline belts	secondary eugeosyncline belts	slaty eugeosyncline belts
Compositition of ore-bearing rocks	pillow lavas	rhyolites rhyodacites	rhyolites	slates
Ore-bearring volcanic formations	tholeiitic	basalt-rhyolitic, basalt-andesite dacide-rhyolitic homodrome	basalt-andesite-dacite-rhyolitic homodrome and antidrome	tholeiitic
Examples	deposits of Troodos complex, Cyprus; of York Harbour and Betts Cove complexes, Newfoundland; Ergani Maden, Turkey	deposits of the Southern Urals, of Northern Caucasus; Rio Tinto, Spain.	Miocene deposits of Japan; deposits of Ore Altai, New Brunswick.	Fylyz-chai, Great Caucasus; Rammelsberg and Meggen, West Germany; Sullivan, British Columbia; Mt Isa, H.Y.C., Australia.

1. The saturation by SiO_2 of basalt mambers results in the disappearance in their mineral composition of the normative olivine (forsterite and fayalite).

2. Basalts and andesites are characterized by Mg and Fe verzus Ca high contents expressed by the reduction of normative wollastonite. This reguliarity is known as the anartosite tendency of maphic magmas differentiation and is apparent in all ore-bearing affinities, as it was suggested recently (Marakushev, 1980).

3. Pyrite-bearing magmatic affinities are characterized also by reduced alkalinity of acid members.

It is well-known that the alkalies accumulation in acid derivates is the main feature of the basaltoid magmas development (Wyllie, 1979). The Fig. 2 represents evolution trends of tholeiitic, calc-alkaline and andesitic affinities

Table 2

Average chemical composition of ore-bearing volcanics in the Caucasus

Oxides	1	2	3	4	5	6	7
SiO_2	51.52	72.99	51.96	57.86	74.16	48.04	55.00
TiO_2	0.71	0.23	0.57	0.43	0.19	0.73	0.69
Al_2O_3	14.68	12.40	16.68	15.38	12.08	19.85	16.70
Fe_2O_3	4.72	1.62	3.64	3.45	1.89	6.01	4.44
FeO	6.35	2.08	6.47	5.85	1.02	3.67	3.49
MnO	0.19	0.09	0.17	0.00	0.08	0.22	0.24
CaO	5.35	1.57	4.86	2.84	1.70	8.93	4.50
MgO	6.45	1.82	5.84	3.96	0.83	4.32	3.17
Na_2O	3.58	0.43	3.02	0.82	2.91	2.76	4.85
K_2O	3.29	0.90	1.30	1.85	0.86	0.83	1.81
Oxides	**8**	**9**	**10**	**11**	**12**	**13**	**14**
SiO_2	61.42	66.73	70.71	75.70	49.97	60.64	71.76
TiO_2	0.76	0.38	0.31	0.27	1.22	0.54	0.35
Al_2O_3	15.49	15.85	13.89	11.53	15.47	16.92	13.18
F_2O_3	3.50	2.17	2.27	1.46	2.30	1.61	1.04
FeO	2.18	1.38	0.84	1.29	8.06	5.17	2.21
MnO	0.12	0.06	0.12	0.04	0.20	0.14	0.07
CaO	3.63	2.19	1.74	1.00	7.45	3.29	2.03
MgO	2.52	1.89	1.20	1.22	6.58	2.64	1.42
Na_2O	4.16	3.75	4.14	3.72	3.65	4.33	4.54
K_2O	2.09	0.90	1.30	1.15	0.86	1.03	1.16

Note: 1—2 - basalts-rhyolitic formation of the Urupe district: 1 - basalts, 2 - rhyolites, 3—5 - basalt-andesite-(dacite)-rhyolitic homodrome formation of the Alaverdi district: 3 - basalts, 4 - andesites, 5 - rhyolites; 6—11 - basalt-andesite-dacite-rhyolitic antidrome formation of the Madneuli district: 6 - basalts, 7 - andesito-basalts, 8 - andesito-dacites, 9 - dacites, 10 - rhyodacites, 11 - rhyolites; 12—14 - volcanics of the Great Caucasus Southern Slope: 12 - tholeiitic formation, 13 - andesites and dacites

Continuation of Tab. 2

Oxides	15	16	17	18	19	20	21
SiO_2	49.94	50.83	48.16	49.84	50.10	72.05	63.58
TiO_2	1.51	2.03	2.91	2.52	1.02	0.35	0.64
Al_2O_3	17.25	14.07	18.31	14.09	15.51	12.50	16.67
Fe_2O_3	2.01	2.88	4.24	3.06	4.24	1.75	2.24
FeO	6.90	9.06	5.89	8.61	6.87	2.93	3.00
MnO	0.17	0.18	0.16	0.16	0.10	0.01	0.11
CaO	11.86	14.42	8.79	10.41	7.43	1.58	5.53
MgO	7.28	6.34	4.87	8.52	6.05	1.34	2.12
Na_2O	2.76	2.23	4.05	2.15	3.35	4.93	3.98
K_2O	0.16	0.82	1.69	0.38	0.57	0.61	1.40

Oxides	22	23
SiO_2	72.08	74.57
TiO_2	0.37	0.17
Al_2O_3	13.83	12.58
F_2O_3	0.86	1.30
FeO	1.67	1.02
MnO	0.07	0.05
CaO	1.33	0.61
MgO	0.52	0.11
Na_2O	3.08	4.13
K_2O	5.46	4.73

14 - rhyolites; 15 - oceanic tholeiites (Engel — Celeste — Engel, 1965); 16 - tholeiites (Nockolds, 1954); 17 - alkaline tholeiites of East Pacific Rise (Engel — Celeste — Engel, 1965); 18 - Hawaiian tholeiites (Mc Donald — Katzura, 1964); 19—20 - average basalt-rhyolitic formation: 19 - basalts, 20 - rhyolites; 21—23 - average composition (Nockolds, 1934) of: 21 - dacites, 22 - calc-alkaline rhyolites, 23 - alkaline rhyolites.

Table 3
Normative mineral composition of ore-bearing volcanics

Minerals	1	2	3	4	5	6	7	8
Q.	5.58	41.50	9.31	30.27	52.37	4.02	6.13	17.24
C	—	3.46	2.45	6.73	6.32	—	—	2.85
or	2.78	5.56	7.79	11.13	33.39	5.56	10.57	12.24
ab	30.41	27.79	25.16	7.34	24.64	23.59	40.39	35.13
ne	—	—	—	—	—	—	—	—
an	22.53	6.95	21.69	14.18	—	33.34	15.96	15.30
$CaSiO_3$	1.39	—	—	—	—	1.53	0.46	—
$MgSiO_3$	16.06	4.52	12.04	9.84	2.71	10.64	7.83	6.32
$FeSiO_3$	6.99	2.24	8.18	7.39	—	0.53	3.43	—
Mg_2SiO_4	—	—	—	—	—	—	—	—
Fe_2SiO_4	—	—	—	—	—	—	—	—
ap	0.34	0.34	1.01	—	—	0.67	1.01	1.68
mt	6.71	2.32	5.32	4.87	2.78	8.80	5.09	5.09
il	1.36	0.45	1.06	0.76	0.45	1.36	1.36	0.15

Minerals	9	10	11	12	13	14	15	16
Q	33.63	38.38	44.50	—	17.54	34.77	—	3.50
C	4.89	2.55	2.65	—	3.26	0.92	—	—
or	6.12	8.35	7.23	1.67	6.68	6.68	1.00	15.00
ab	31.98	35.13	31.46	30.93	36.70	38.80	23.59	18.92
ne	—	—	—	—	—	—	—	—
an	10.01	8.07	4.18	25.03	14.46	9.46	33.93	25.91
$CaSiO_3$	—	—	1.74	4.18	—	—	10.22	10.32
$MgSiO_3$	40.71	3.01	3.01	15.56	6.52	1.00	13.54	15.83
$FeSiO_3$	—	—	0.79	10.81	7.52	2.90	6.99	11.22
Mg_2SiO_4	—	—	—	0.70	—	—	3.24	—
Fe_2SiO_4	—	—	—	0.41	—	—	2.85	—
ap	0.34	0.34	0.34	0.67	0.67	0.34	0.34	0,51
mt	3.47	2.85	2.08	3.24	2.32	1.39	2.78	4.20
il	2.32	0.61	0.61	2.28	1.06	0.61	2.88	3.80

Continuation of Tab. 3

Minerals	17	18	19	20	21	22	23
Q	—	12.54	3.48	35.86	19.60	29.00	31.10
C	—	—	—	1.53	—	—	—
or	10.2	2.23	3.34	3.34	8.30	29.50	27,80
ab	27.79	17.82	27.26	39.85	34.10	25.71	35.10
ne	3.69	—	—	—	—	—	—
an	24.62	27.81	26.15	23.31	26.42	6.42	2.00
$CaSiO_3$	6.85	9.52	3.72	—	1.30	0.71	0.12
$MgSiO_3$	4.82	21.18	15.05	3.31	5.30	0.92	0.30
$FeSiO_3$	1.45	9.50	7.65	3.43	2.81	4.10	0.61
Mg_2SiO_3	5.06	—	—	—	—	—	—
Fe_2SiO_4	1.22	—	—	—	—	—	—
ap	0.34	0.34	0.67	0.34	0.32	0.20	0.20
mt	6.02	4.40	6.02	2.55	3.30	1.40	1.90
il	5.46	4.70	1.97	0.61	1.21	1.80	0.30

Note: analysis numbers are the same that those of the Tab. 2.

(a) as well as that of ore-bearing formations. The diagram shows the bend of the evolution curves of ore-bearing formations from andesites.

Thus, the origination of hydrothermal systems is connected with the mechanism of deep-seated petrogenesis. As such mechanism is quite different during bimodal, homodrome, and antidrome magmatic evolution, the origination processes of pyrite-bearing systems would differ from each other.

Tholeiite bimodal series

Numerous investigation (Marakushev, 1976; Pertchuk, 1973) indicate that tholeiitic basalts are smelted at moderate depth (40—60 km). This process is considered as a result of the interaction of transmagmatic fluids with the ultramaphic upper mantle. The moderate depth of tholeiitic smelts results in the sodium trend of magmas due to the well-known low of alkalies distribution between solid and melt phases. A high fluid pressure (4—6 kbar) results in the uplift of magmas toward the Earth crust, where intermediate (after F e d o-t o v) magmatic hearths are to be formed.

Many investigators consider that the evolution of tholeiites is due to the crystallization differentiation, but such a mechanism is very difficult to be imaginated for the bimodal stratification of melts. In this connection M a r a k u-s h e v (1976), (M a r a k u s h e v — Ýa k o v l e v a, 1975) has suggested an

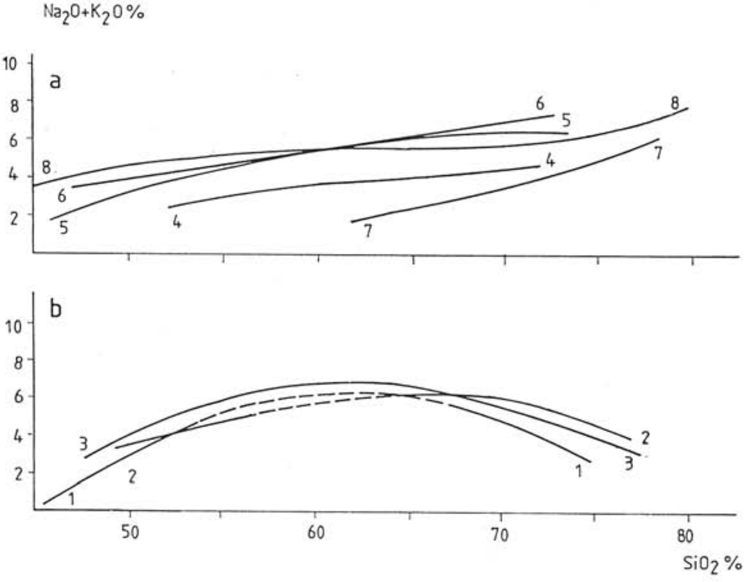

Fig. 2. Evolution trends of magmatics associations main types (a) and ore-bearing formations (b).
Ore-bearing formations: 1 — of Urupe district, 2 — of Alaverdi district, 3 — of Madneuli district; main volcanic series: 4 — tholeiitic (E n g e l, C e l e s t e, and E n g e l, 1965), 5 — calc-alkaline (K u n o, 1966), 6 — andesitic (O s t r o u m o v a, 1978); post-ore volcanic formations: 7 — of Alaverdi district, 8 — Madneuli district.

idea on the liquation nature of such stratification as a result of fluid melt interaction. Such a process can be proved by some petrologic facts. Fig. 3 shows, for instance, a tendency of Fe accumulation verzus Mg in basic and acid members of the bimodal basalt-rhyolite formation of the Urupe district (Northern Caucasus). It could be seen a splitting of the evolution trend in maphic rocks at the lowest level of of acid volcanics (1a and 1b curves). Hence, before the smelting of rhyolitic magmas a basic reconstruction of crystallization conditions took place, due to liquid immicibility. It could be noted, by the way, that the same method was used by M a r a k u s h e v (1980) when he suggested a liquation of ultrabasic magma during the formation of the Great Dyke.

The thermodynamics of fluids isolation from the crystallizing melt is considered in many contributions. Z h a r i k o v (1979) suggests that the composition of a fluid phase equilibric with a melt depends on their basic-acid interaction. In common (Marakushev — Yakovleva, 1975), as F, characterized by well-expressed affinity with K, do not distribute in fluid phase, the accumulation of K verzus Na takes place in the melt, whereas Cl verzus F does migrate in the fluid.

Thus, a fluid phase isolated from a melt would characterized, on the one hand, by acid reaction, and by sodium chloride composition - on the other.

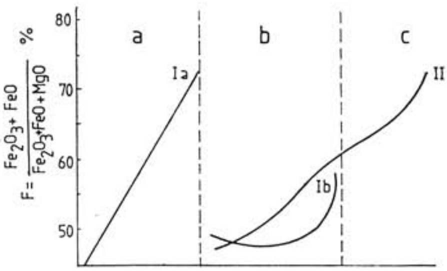

Fig. 3. Variations of bulk Fe contens in ascending section of the basalt-rhyolite formation in the Urupe district.
Explanations: a — maphic rocks, b — interbedding of maphic and acid rocks, c — acid rocks. Evolution trends: I — of maphic rocks, II — of acid rocks.

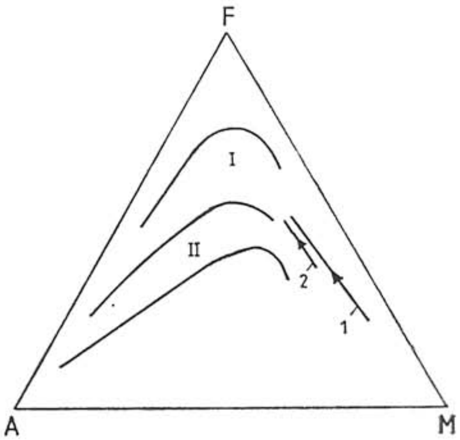

Fig. 4. AFM diagram for lower pillow--lavas of ore-bearing ophiolitic complexes.
Explanations: 1 — Troodos complex, Cyprus (Coleman, 1979); 2 — York Harbour complex, Newfoundland (Duke, Hutchinson, 1974).

In basalt-rhyolite ore-bearing melts the removal of the fluid phase proceeds any differently, directly in the intermediate chamber. If such a fluid phase should be an energetic base of pyritebearing hydrothermal systems, then would originate long before the formation of the central type volcanic constractions. On the other hand, as the petrodynamics under volcanos entirely differś from a volcanic process (Kutijev – Sharapov, 1979), the final crystallization of residual melt and corresponding generation of the fluid phase may terminate many hundred thousands years after the active volcanism. Thus, in our opinion, may be formed long-living hydrothermal systems.

Homodrome and antidrome calc-alkaline series

The described mechanism of a liquid differentiation couldn't be used for homodrome formations, intrusive equivalents of which are crystallized according the Bowen's range. The formation of such series is commonly explained by a subsequent hibridism of the Earth crust by astenospheric basaltic magmas (Frolova et al., 1974). So, Marakushev (1976) suggested that during the development of island arcs the volcanics differentiation degree was gradually chainging. First of all against the background of the oceanic crust initiation the undifferentiated tholeiitic volcanism took place. Subsequently, when the sialic crust originated the central type stratovolcanoes and their intermediate magmatic hearthes were formed. In these chambers the deep-seated calc-alkaline basalts under went differentiation resulting in the formation of andesitic rocks.

This general sketch of island arc volcanism requires some corrections when concret volcanic formations are under discussion, because does not explain volcanics rythmical alternation in the ascending section of geosyncline sequences. It must be noted, by the way, that only basaltic members of differentiated formations could be regarded as "pure" astenospheric magmas, whereas their differentiation is related to concret stratovolcanoes. Then it may be thought that basalts differentiation character is due to the petrodynamics in the volcanic construction roots (Kutijev – Sharapov, 1979) and first of all - to the vital activity of volcanic hearts. If such a process could be imaginated after Fedotov (1980) as self-regulated system, then the production of consequently more acid rocks must be related to the partial melting of hast rocks the uplift of these palingenic magmas resulting in the formation of homodrome series.

During the discontinuance of volcanic activity the reduce of an endogenic energetic flow must result in the "drainage" of the intermediate chamber.

The opposit situation is presented in antidrome formations, typical for many Kuroko-type deposits (Ore Altai, New Brunswick, Bulgarian Srednegorjé). In such districts, connected with peripherial parts of tention zones, must be provided no conditions for active reduction of the sialic crust during the geosynclinal process, the magmatic events being thus related to the crustal matter. So, volcanism in these regions is initially connected with large stratovolcanoes, often having "multiroot" systems. Relatively stable tectonic environment results in stable petrogenesis proceeding during many million years under the conditions of a constant heat flow. After Fedotov (1980) the magmatic chambers reaching optimum dementions remain its quasistationar state and do not alter heat and mass transfer. In such conditions magmas gravitation-crystallization differentiation is active resulting in the formation of two or several zones, the acidity of which being gradially increased from the chamber centre towards its periphery. The removal of external and then of central melt portions produces antidrome volcanic formations.

In described homodrome and antidrome formations base metal massive sulphide deposits seem to be connected with acid volcanics. So, hydrothermal systems of corresponding deposits originated after the formation of basic rocks in homodrome series and before its smelting in antidrome affinities. The above mentioned petrochemical data on ore-bearing formations must be considered just from this point of view. In the other words the formation of rocks of moderaite acidity is the general event for the genesis of pyrite-bearing hydrothermal systems.

It is interesting to note that after the Fedotov's model just the productions of andesitic rocks outline the turning-point of the intermediate hearthes development. In homodrome formations these rocks are formed in the case of chamber grows under the influence of a heat flow, while in antidrome sequences such lavas indicate the decrease of a heat flow and the chamber reduce. The origination of hydrothermal systems expressed by magmas retrograde boiling takes place during unstable conditions when fluid-melt equilibria are broken. It must be outlined in addition that irrespective to the concret petrologic mechanism of the fluid phase isolation, it always would be enriched by Cl and Na, because the alkalies distribution low is common in all cases.

Undifferentiated tholeiites of ophiolite and slaty belts

Thick feasure eruptions of pyrite-bearing ophiolite pillow-lavas without any differentiation signs (Fig. 4) are rather petrologically like tholeiites of ocean median ridges being formed in the same geodynamic environment (Coleman, 1979). Roughly the analogic features are characteristic of basaltic rocks in slaty sequences.

It was mentioned above that tholeiite magmas are smelted at a depth about 40—60 km as a result of fluid-magmatic differentiation of the mantle matter. Petrologic data (Coleman, 1979) suggest a quick uplift of tholeiitic melts in ophiolitic zones, producing no conditions not only for melt-rock interaction, but for deep-seated isolation of the fluid phase too. The volatile removal seem to take place at a subvolcanic level as a result of magma retrograde boiling. It is interesting to outline that the initial crust state in ophiolitic zones and the absence of ramified volcanic roots prevent the endogenic petrogenesis and limit the energetic "feeding" of volcanoes by a single mantle plume.

Approximatly the same situation is presented in slaty sequences where the connection of feasure tholeiitic lavas with sialic crust tention zones are proved by a lot of geologic data (Adamia, Buadze — Shavishvili, 1977). The tholeiitic melt here undergoes a complex ascending way in deep-seated faults through the destructing continental crust, but does not form intermediate hearthes and chambers; that is proved by the absence of a tendency of magma differentiation. Therefore a fluid phase of the melt is able to remove only at the subvolcanic level. Such subsurface brines have nothing in commom wih ore-bearing solutions and result in only autometasomatic alteration of tholeiitic lavas with initial signs of its pyritization. Therefore, the generation of hydrothermal systems is related directly to the process of liquid differentiation of the upper mantle during magma smelting. This process results in reduction of basalts alkalinity and of their potassium content, which is less then in oceanic tholeiites (Tab. 2).

Conclusions

Above mentoined petrologic data on the relation of pyrite-bering solutions to the magmatism implicate heterogenous conditions of hydrothermal systems generation due to different geological processes. In all cases, however, the energetical and material base of hydrothermal systems is presented by a magmatic hearth.

It is necessary to note that irrespective to concret petrologic mechanism fluids removed from magmas would be enriched in Cl and Na and have acid reaction due to the universal low of alkalies partition. The removal of fluid phase from the ore-bearing melt proceeds repeatedly, but only those fluid flows, which were formed at a depth (exept Cyprus type deposits) at the lowest levels adjoined an intermediate ore main magmatic hearth, are able to manifest as ore-forming pyrite-bearing systems. From this point of view an uneven evolution trend ore-bearing complexes can be explained, because such magmas during smelting of andesites or the liquation process have lost their volatiles and became unable to accumulate alkalies in acid members.

During consequent evolution primary magmatic fluids underwent a long evolutional way mixing with waters of quite different genesis and requiring the corresponding composition of oxygen and hydrogen isotopy.

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