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# MAFIC AND ULTRAMAFIC ROCK ASSOCIATIONS — INDICATORS OF TECTONIC SETTING

*(Tabs. 3)*

A b s t r a c t: Associations of mafic and ultramafic rocks (with minor other differentiates) are of subcrustal origin. Small differences among these rocks indicate their origin in different geotectonic environments. This is very important both for compilation of geotectonic maps and interpretation of geologic evolution. The following associations can be distinguished:

1. Mafic rocks only (with minor acid differentiates).

1.a. Alkaline and/or tholeiitic basalts; 1.b. gabbros; 1.c. gabbro-basaltic associations. 1.a—c.: volcanic to intrusive bodies originated by crystallisation of subcrustal melts rising along deep fractures in the continental plates, mostly in rifting zones, where in some places hybridized.

2. Ultramafic rocks only.

2.a. Ultramafic rocks of igneous fabric; 2.b. ultramafic rocks of tectonite fabric. 2.a, b.: often serpentinized and sheared. They represent mostly fragments of group 3-rocks, but may originate by crystallisation of (rare) ultramafic melts (2.a.) or by high temperature diapiric intrusion (2.b.); 2.c. serpentinites without relics, mostly strongly deformed — tectonic blocks or low temperature diapirs.

3. Association of mafic and ultramafic rocks.

3.a. Rocks of igneous fabric: layered intrusions (in continental crust) or upper parts of ophiolite complexes (separated from deeper parts); 3.b. rocks of tectonite fabric: separated lower parts of ophiolite complexes (including dyke rocks); 3.c. rocks of igneous and tectonite fabric: ophiolite complexes (fragments of oceanic lithospere).

Р е з ю м е: Ассоциации мафических и ультрамафических пород (с другими второстепенными дифференциатами) подкорового происхождения. Малые различия между этими породами показывают на их образование в разных геотектонических средах. Это важно не только для составления геотектонических карт, но и для интерпретации геологической эволюции. Были выделены следующие ассоциации:

1. Только мафические породы (с второстепенными кислыми дифференциатами).

1.а. Щелочные и/или толеитовые базальты: 1.б. габбро; 1.в. габбро-базальновые ассоциации. 1. а—в.: вулканические и интрузивные тела возникли кристаллизацией подкоровых расплавов выходящих на поверхность вдоль глубоких разломов в континентальных плитах, преимущественно в рифтовых зонах, где они были на некоторых местах гибридизованные.

2. Только ультрамафические породы.

2.а. Ультрамафические породы магматической текстуры; 2.б. ультрамафические породы тектонитовой текстуры. 2.а,б.: часто серпентинизован-

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ные и рассланцованные. Они представляют главным образом обломки пород 3-ьей группы, но они могли быть образованы кристаллизацией (редких) ультрамафических расплавов (2.а.) или высокотемпературной диапировой интрузией (2.б.); 2.в. серпентиниты без реликтов, преимущественно сильно деформированные — тектонические блоки или низкотемпературные диапиры.

3. Ассоциация мафических и ультрамафических пород.

3.а. Породы магматической текстуры: слоистые интрузии (в континентальной коре) или верхние части офиолитовых комплексов (отделенные от глубоких частей); 3.б. породы тектонитовой текстуры: отделяют нижние части офиолитовых комплексов (включая дайковые породы); 3.в. породы магматической и тектонитовой текстуры: офиолитовые комплексы (обломки океанической литосферы).

The associations of mafic and ultramafic rocks, with minor amounts of other rocks (excluding the leucite bearing and nepheline rich rocks) are of subcrustal origin. These rocks of named associations, however, display some differences both in composition and fabric. The associations also differ, but there exist only certain rocks or rock-groups occuring together.

The differences in composition and fabric are related to different degree of melting, to different depths where the partial melting in the mantle takes place, and to some compositional differences in the mantle. Since the degree of melting and the pressure during the melting depend on the intensity of heat flow, the depth, and the position in the upper mantle (below the oceanic or continental crust), then the position of the mafic and ultramafic rock associations in the crust is critical for estimation of the geotectonic settings and characteristic of the area during the formation of these rock associations.

The differences in composition of mafic and ultramafic rocks and/or rock associations can be related to the differentiation processes during the rise of

Table 1

Associations of mafic and ultramafic rocks

| | |
|---|---|
| 1. Mafic rocks only | |
| a) basalts, tholeiitic/alkaline | |
| b) gabbro only | |
| c) basalt-gabbro association | |
| d) komatiites (will not be discussed here) | |
| 2. Ultramafic rocks only | |
| a) igneous peridotites partly to completely serpentinized (with relict igneous texture) | |
| b) tectonite peridotites partly to completely serpentinized (with relict tectonite texture) | |
| c) serpentinites without relics of primary rocks features | |
| 3. Association of mafic + ultramafic rocks | |
| a) igneous fabric only | — layered intrusions |
| | — association of basalt, gabbro, and igneous peridotite — nonophiolitic |
| | — upper parts of ophiolite complexes |
| b) tectonite fabric only | — lower parts of ophiolite complexes |
| c) igneous + tectonite fabric | — ophiolite complexes (often dismembered) |

Table 2a

Origin of the association of only mafic rocks (not included dismembered upper parts of ophiolite complexes)

A) Basalts only
— mostly slightly differentiated or contamined. The association is related to deep fractures in the continental crust or to intracontinental rifts, i. e. to the initial phases of intracontinental basins which may further develop or remain undeveloped, or it may occur above hot spots.
1) *tholeiitic basalt* (continental tholeiite) associated with subordinate to abundant (depending on time of rise, and related differentiation and contamination of magma) porphyrite, keratophyre, and quartz keratophyre (sodic andesite, trachyte and rhyolite); by higher contamination of material of the continental crust they may be enriched in potassium, silica etc.
2) *alkaline basalt* associated with subordinate trachytic (sodic) to nepheline bearing rocks.

Rocks of the first association crystallize from magmas originated by partial melting in high levels of the upper mantle, and the ones of the second association from magmas originated by partial melting at greater depths of the upper mantle. These associations indicate rifting of the crust because of the increase of heat in the upper mantle and to mantle diapirism below the crust.

B) Gabbro only
— the same as for (a), it occurs if the erosion was significant, and has exposed the roots of basaltic masses.

C) Basalt-gabbro association
— the same as for (a), but occurs only if the erosion was not very intensive (about 100—1000 m) and volcanic, as well as intrusive facies are exposed.

Table 2b

Origin of associations of only ultramafic rocks (not included dismembered lower parts of ophiolite complexes)

a) Ultramafics of igneous origin
— igneous peridotite partly to completly serpentinized, with relics of igneous fabric.

Rocks originated by crystallization of magmas originated by high degree of partial melting of upper mantle and intruded along very deep fractures. Transitions to (1b) — gabbroperidotites and feldspar bearing peridotite, or to (1a) — picritic basalt exist.

Significance as for mafic associations, but indicates a more intense heat flow in the basement.

b) Tectonite ultramafics
— tectonite peridotite partly to completly serpentinized, with relics of tectonite fabric.

Blocks or slabs of depleted upper mantle moved upwards along deep faults. Spinel bearing facies indicate origin from higher levels, garnet bearing facies originated primary at deeper levels of the upper mantle.

Occurence of these rocks indicates the sequence: mantle plume — fragments of upper mantle pulled into the fault zones (mostly reverse) along continental margins — further upwards movement (as lenticular or diapiric bodies) of rigid or mobile ultramafic masses.

c) Serpentinite without relics
— completly serpentinized igneous ultramafic rocks.

Originated from rocks of the groups (IIa) and (IIb) but completly serpentinized, and because of serpentinization mobile and mostly later displaced.

Mostly serpentinite lenses squeezed out of a subducting slab and diapiricaly moved upwards over subduction zones.

Table 2c

Origin of associations of mafic + ultramafic rocks

a) Rocks of igneous fabric only
— Layered (stratiform) gabbro-peridotite intrusions — related to old shields and not considered here.
— Mafic + (subordinate) ultramafic rocks association — combined (1) and (2a) — developed by differentiation of mafic associations as in (1).
This association indicates similar conditions as for (1) and (2a), but with intensive partial melting of the upper mantle and slow magma rise with stopping in larger magma chambers to differentiate.
— Separated upper parts of ophiolite complexes — will be analysed with ophiolites.

b) Rocks of tectonite fabric only
— separated lower parts of ophiolite complexes — will be analysed with ophiolites.

c) Ophiolite complexes

The complete sequence is:

Thickness and abundance of members vary very much. The sequence is often dismembered.

oceanic crust
- basaltic lavas
- sheeted dyke complex (diabases)
- gabbro zone
  - ± plagiogranite
  - massive gabbro
  - layered gabbro
  - igneous ultramafics

upper mantle — tectonite ultramafics

The rocks of the oceanic crust are frequently affected by ocean-floor metamorphism.

The presence of ophiolite complexes, complete or dismembered, indicates the existence of previous oceanic lithosphere in the area and may be indication of a subduction zone if other diagnostical features are present (calc-alkaline magmatism, metamorphism etc.).

magmas and their stopping during rise, as well as to the reactions with the host crust through which they pass. Since the oceanic crust has almost the same or very similar composition as these magmas, their passing through the oceanic crust will not bring about alterations in composition due to contamination. On the other hand, if these magmas pass through the continental crust changes of their composition, (due to) reactions with the surrounding crustal rocks, may be important. It has to be mentioned that in the oceanic crust sea-water penetrates deep into the rocks, what gives rise to hydrothermal ocean metamorphism or alteration in chemical composition.

In the following tables the characteristics of the mafic and ultramafic rock associations are summarized: in the first one different associations are listed, in the second one the main characteristics and origin of the associations are given, and in the third one some main features of the mafic and ultramafic rocks or rock associations building the oceanic crust, or, in another words, the characteristics of ophiolite assemblages or complexes are presented. All these tables are compilled on the basis of generally accepted modern

Table 3

Types of oceanic environments with ophiolite assemblages and other geological features related to the closure of oceanic area by subduction combined with obduction

| | Margins of large oceanic areas far away from the zone of high heat flow | Narrow oceanic areas near to the zone of high heat flow | Marginal seas — zones of increased heat flow |
|---|---|---|---|
| Tectonite ultramafics | metamorphic gneissoid fabric well developed | metamorphic gneissoid | fabric less developed |
| Gabbro | partly layered, differentiated | layering rare, differentiated | less differentiated |
| Plagiogranite — keratophyre | very rare | abundant | abundant |
| Dyke complex | sheeted dykes, regular | regular sheeted dyke complex or irregular (vertical ± horizontal dykes and small bodies) | |
| Basaltic lavas | tholeiitic (oceanic tholeiite) — rare alkaline basalts | tholeiitc (oceanic tholeiite) | tholeiitic, rare calc-alkaline rocks |
| Associated sediments | pelagic | terigenous<br>abundant olistostrome melange | terrigenous — pelagic |
| Sediments in trench | olistostrome melange, with turbidite interlayers and occasionaly lavas | | |
| Metamorphism below obducted ophiolites | high P — low T | middle (to high) P — high to low T | |
| Post-collisional formations | tectonic melange (if compression continues after collision) | | |
| Associated formations | calc-alkaline igneous rocks (not of the granite-rhyolite assemblage) over the subducted slab, about 150—400 km from the trench | — | locally as for large oceanic areas |

concepts on ophiolites (Coleman, 1977 and 1984) as well as on our own experience on Mediterranean ophiolites.

The determination of the type of mafic and ultramafic rock associations is very important for the explanation of the geological history and evolution of an area and therefore it is necessary to present their separate groups on the geotectonic maps.

Considering the mentioned afore we have to add that here are presented only the main groups and their most typical characteristics, but today many very precise and exact methods (using chemical and mineralogical composition, trace elements discriminant distribution, stable isotops etc.) for determination of genetic aspects of these rocks are developed.

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