

39. DISTRIBUTION OF GASES AND BITUMENS IN BASALTS FROM HOLES 395 AND 396, LEG 45

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Young basalts distributed in oceanic islands and island arcs are characterized by a relatively narrow range of chemical composition of gases. The total gas content in these rocks is not more than 1 cm³/kg. But rocks subjected to epimagmatic changes can contain more than 10 cm³/kg of gases, mostly CO₂ (Voitov et al., 1970; Zolotarev et al., 1976). The established narrow range of chemical composition and concentration of gases in basalts is a result of loss of gases at the epigenetic stage.

To determine the peculiarities of the chemical composition and concentrations of gases and bituminous matter in young basalts of the mid-oceanic ridge, we studied all structural-petrographic varieties of rocks from Holes 395 and 396 (see Chapters 7 and 8, this volume).

Gas extracts were obtained from 2-gram samples crushed in hermetically sealed argon-filled chambers. The gases were analyzed chromatographically. Low-boiling gases (He, H₂, N₂, O₂, CO₂, CO₄) were determined by Device LKHM-7A equipped with a catarometer. Very low hydrocarbon contents were determined using Device VX-2 with a flame-ionization detector; the threshold of sensitivity of this device was 10⁻⁵ per cent by volume. The bitumen extracts were studied by the luminescence technique. Bitumen was extracted from micro-samples of the same material, using the cold extraction method, followed by treatment with chloroform and alcohol-benzol. The distribution of bitumens was studied on fresh surfaces of samples and during their disintegration was studied using an ultraviolet microscope. Examination of the fresh surfaces enabled us to determine associations of bitumens and gases in open cracks, and in spaces between crystals and grains of rocks. Bitumens in minerals were studied on the individual grains of crushed samples.

The gas content in rocks (Table 1, Figure 1) is not high (<1 cm³/kg), but is somewhat higher than in basalts of the islands of the southwestern sector of the Pacific Ocean and the Kuril Island arc. The gas content of rocks sharply increases when CO₂ becomes predominant. The number of such samples, however, is not large (less than 10% of the samples studied). Accordingly, the chemical composition of gases of most basalts can be determined by measuring the amount of hydrogen and hydrocarbons. Unaltered basalts, gabbro, and serpentinized peridotites are characterized by the highest hydrogen and hydrocarbon contents. The effusive rocks, which are more or less altered, and

brecciated rocks contain appreciably lesser amounts of these gases. The spectrum of hydrocarbons whose abundance exceeds the sensitivity threshold of the flame-ionization detector is narrow (CH₄, C₂H₆, C₂H₄, and C₃H₈). The relative content of methane homologs (mainly C₂H₄ and C₃H₈) in the most thoroughly studied samples reaches 10 per cent and more—i.e., the hydrocarbons are mostly "heavy." This is well illustrated in Figure 2a, where the spread of the ratio of CH₄ to heavy hydrocarbons varies within two orders of magnitude, whereas the CH₄ content is smaller. The influence of the petro-chemical composition of samples on the CH₄ content and the ratio of CH₄ to heavy hydrocarbons proves insignificant.

Hydrogen is more unevenly distributed in the basalt samples studied (Figure 2), but is not correlated with the petrochemical composition or rocks.

Thus, one can think of a distinct association of gases not in the matrix of a rock, but in its mechanical and crystalline defects, fractures or cracks, intercrystalline spaces, and other defects of structure.

Structural defects are especially evident in studying the distribution of the bituminous matter in rocks. In particular, a dispersed distribution of bitumens, those intensively desorbed only during decomposition of their mineral host, occurs in only 35 to 36 per cent of samples. In the rest, the predominant portion of bitumens desorbed by chloroform is present as "films" along fissures and in intercrystalline spaces, or is concentrated as condensed drops in vesicles. When the bituminous matter is being dissolved in chloroform, the drops (pores?) look like bubbles or gaseous bitumen inclusions.

The total amount of bitumens in the basalts studied is not great (Table 2). The rocks most enriched in bituminous matter are those that underwent relatively low-temperature processes of hydration (serpentinized peridotites). The next most enriched are those with a coarse-crystalline structure acquired in magma chambers (gabbros); these are followed by fine-grained to glassy basalts (doleritic, porphyritic, and aphyric basalts). Bitumens of the two first groups of rocks are heavily reduced carbonaceous compounds (the bitumen content of a chloroform extract of bitumen A is sometimes higher than that of the alcohol-benzol extract of bitumen A).

The relationships between the contents of the chloroform and the alcohol-benzol extracts of bitumen A in the basalts vary because of a very uneven (irregular)

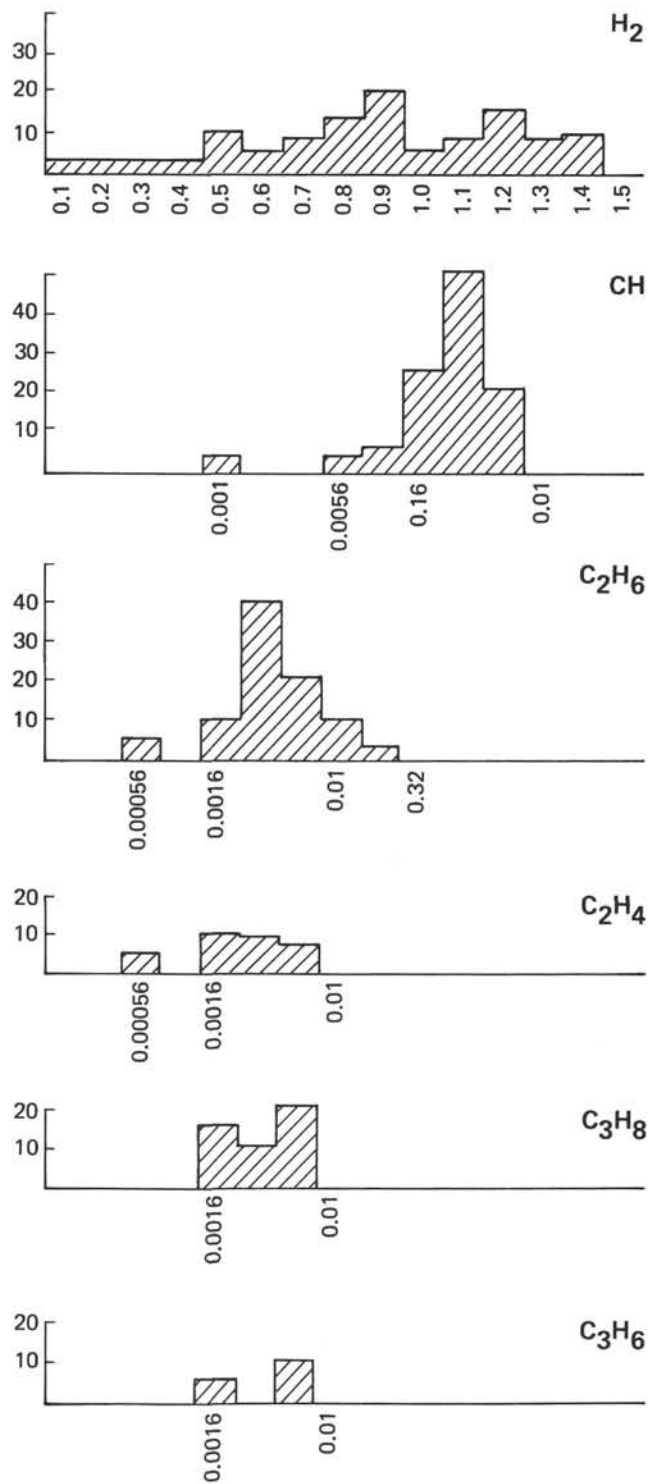


Figure 1. Histograms of gas distribution.

amount of oxidized bitumen in rocks. Accordingly, the histogram showing distribution of the chloroform extract of bitumen A is close to the Gauss distribution (Figure 3). Analysis of distribution of bituminous matter in individual samples (Table 3) shows that chloroform bitumen A is most frequently present as "cellular" (honeycomb) films, as finely dispersed forms, as microdrop inclusions, within and conforming

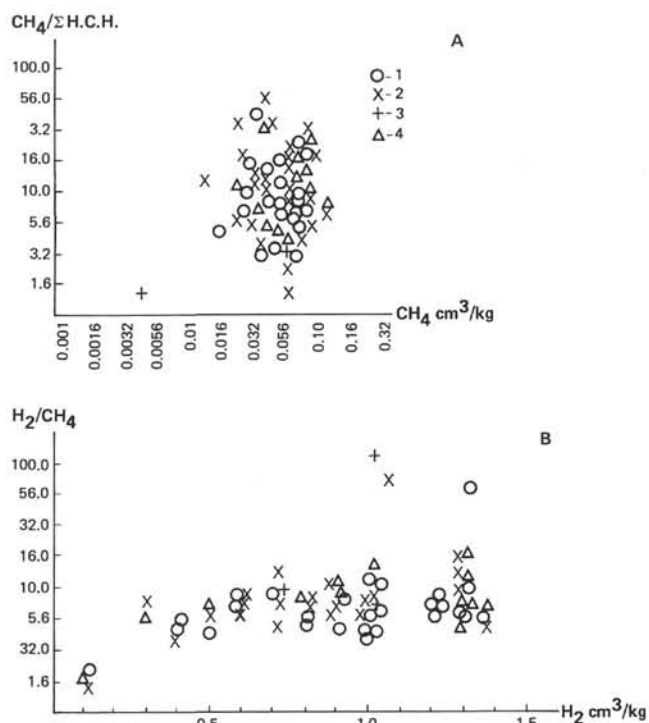


Figure 2. Variation diagrams of relationships between gases. Symbols: \circ circle – aphyric basalts; \times – porphyritic plagioclase-olivine basalts; $+$ – doleritic basalts; triangle – porphyritic plagioclase-olivine-clinopyroxene basalts.

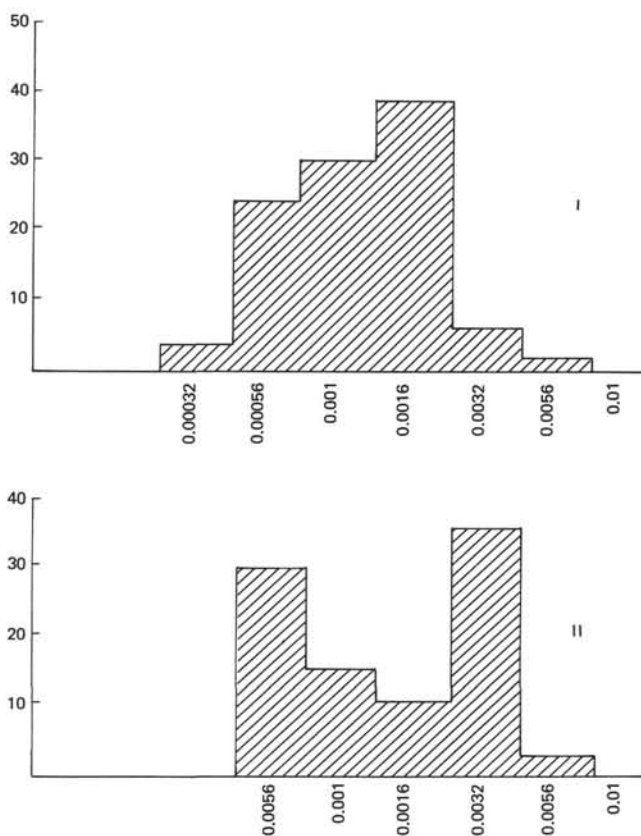


Figure 3. Histograms of distribution of chloroform bitumen A (I) and alcohol-benzol bitumen A (II).

TABLE 1
Chemical Composition and Gas Content in Rocks

Rock Type	Number of Samples	Chemical Composition					
		H ₂	CO ₂	CH ₄	C ₂ H ₆	C ₂ H ₄	C ₃ H ₈
Peridotite, serpentinous	2	<u>13.97</u> 1.25(1.0-1.5)	<u>83.90</u> 7.5(0.0-15.0)	<u>1.34</u> 0.12(0.103-0.132)	<u>0.67</u> 0.06(0.004-0.009)	—	<u>0.12</u> 0.0085
Gabbro	1	<u>89.7</u> 1.20	—	<u>9.3</u> 0.132	<u>0.7</u> 0.001	<u>0.1</u> 0.002	<u>0.4</u> 0.006
Dolerite	4	<u>13.93</u> 0.82(0.6-1.0)	<u>84.97</u> 5.0(0.0-20.0)	<u>0.85</u> 0.05(0.005-0.08)	<u>0.17</u> 0.01(0.004-0.012)	<u>0.035</u> 0.002(0.000-0.004)	<u>0.035</u> 0.002(0.000-0.006)
Basaltic glass	3	<u>10.5</u> 0.60(0.3-0.9)	<u>88.6</u> 5.0(0.0-15.0)	<u>1.2</u> 0.07(0.051-0.08)	<u>0.2</u> 0.01(0.003-0.008)	—	<u>0.02</u> 0.001(0.000-0.004)
Aphyric basalt, variolitic	2	<u>9.82</u> 1.1(1.0-1.2)	<u>89.62</u> 10.0(0.0-20.0)	<u>0.62</u> 0.07(0.036-0.098)	<u>0.04</u> 0.0055(0.005-0.006)	—	—
Aphyric basalt, glassy	8	<u>15.4</u> 0.96(0.6-1.3)	<u>84.8</u> 5.6(0.0-20.0)	<u>0.9</u> 0.06(0.041-0.11)	<u>0.1</u> 0.008	<u>0.01</u> 0.0008	<u>0.01</u> 0.0008
Aphyric basalt	28	<u>20.2</u> 0.9(0.1-1.4)	<u>77.7</u> 3.5(0.0-45.0)	<u>1.3</u> 0.06(0.02-0.103)	<u>0.2</u> 0.01(0.001-0.017)	<u>0.02</u> 0.001(0.000-0.006)	<u>0.06</u> 0.003(0.000-0.048)
Porphyritic basalt, plagioclase	1	<u>10.7</u> 0.60	<u>89.0</u> 5.0	<u>0.5</u> 0.03	<u>0.05</u> 0.003	—	—
Porphyritic basalt plagioclase-olivine	28	<u>2.84</u> 0.5(0.1-1.5)	<u>97.6</u> 17.0(0.0-65.0)	<u>0.39</u> 0.07(0.015-0.132)	<u>0.39</u> 0.007(0.000-0.012)	<u>0.005</u> 0.001(0.000-0.007)	<u>0.02</u> 0.004(0.000-0.032)
Porphyritic basalt plagioclase-olivine-clinopyroxene	16	<u>17.42</u> 1.0(0.1-1.5)	<u>81.53</u> 4.68(0.0-25.0)	<u>1.04</u> 0.06(0.030-0.151)	<u>0.104</u> 0.006(0.002-0.021)	<u>0.016</u> 0.001(0.000-0.004)	<u>0.016</u> 0.001(0.000-0.019)
Porphyritic breccia of plagioclase-olivine basalt	2	<u>94.01</u> 1.1(1.0-1.2)	—	<u>5.13</u> 0.064(0.037-0.091)	<u>0.513</u> 0.006(0.001-0.011)	<u>0.085</u> 0.001(0.000-0.002)	<u>0.256</u> 0.003(0.000-0.006)
Breccia of glassy basalt	1	<u>95.13</u> 1.0	—	<u>4.85</u> 0.052	<u>0.02</u> 0.004	—	—
Basalt	1	<u>87.89</u> 0.90	—	<u>10.45</u> 0.107	<u>1.05</u> 0.011	<u>0.28</u> 0.006	<u>0.33</u> 0.007

Note: Numerator: average content, %. Denominator: average content and the limits, cm³/kg.

TABLE 2
Bitumen Content in Rocks

Rock Type	Number of Samples	Bitumens, Per Cent by Weight		Ratio of Chloroform Bitumen (A) to Alcohol-Benzol Bitumen (A)
		Chloroform A	Alcohol-Benzol	
Peridotite-serpentinized	2	0.0018	0.0006	3.0
Gabbro	1	0.0018	0.0006	3.0
Dolerite	4	<u>0.0018</u> 0.0012-0.0024	0.0036	0.5
Basaltic glass	3	<u>0.00085</u> 0.00045-0.0012	<u>0.0016</u> 0.0006-0.0036	0.5
Basalt, aphyric glassy	2	0.0009	<u>0.0021</u> 0.0006-0.0036	0.43
Basalt, aphyric variolitic	8	<u>0.0012</u> 0.0009-0.0024	<u>0.0019</u> 0.0006-0.0036	0.63
Basalt, aphyric	28	<u>0.0014</u> 0.00045-0.0049	<u>0.0016</u> 0.0006-0.0049	0.85
Basalt, porphyritic, plagioclase	1	0.0024	0.0006	4.0
Basalt, porphyritic, plagioclase-olivine	30	<u>0.0021</u> 0.00045-0.009	<u>0.0027</u> 0.0000-0.0049	0.8
Basalt, porphyritic plagioclase-olivine-clinopyroxene	16	<u>0.0012</u> 0.0009-0.0024	<u>0.00108</u> 0.0006-0.0036	1.1
Breccia basalt-porphyritic	2	0.0024	<u>0.0042</u> 0.0036-0.0049	0.63
Breccia of basalt, glassy	1	0.0012	0.0018	0.66
Basalt	1	0.0018	0.0036	0.50

Note: Numerator: average content. Denominator: limits of contents, %.

to the shape of light fraction films, etc. The gaseous-filmy phase of the chloroform bitumen A extract is common to small cracks. It is usually "sealed" with

chloroform bitumen A, and manifests itself in samples crushed to <0.5 mm, or in desorption of chloroform bitumen A. The gaseous-filmy phase is frequently associated with dark aggregates with a peculiar size—of the order of 2 mm and smaller. The gaseous phase is associated with serpentine veins (in peridotites), or is in microvesicles, or is dissolved ("sealed") in the bituminous matter and boils during its dissolution. It also occurs in dark minerals, and is released after dissolving a chloroform constituent of bitumen A. Its properties sometimes approximate those of condensates.

Thus, basalts of the Mid-Atlantic Ridge contain gases mostly of the hydrocarbon-hydrogen composition. Gases constitute less than 1 cm³/kg of fresh rocks, but the amount becomes considerably higher if CO₂ is predominant in the gas composition. In most samples the main component of gases is hydrogen. The hydrocarbons in gases of the basalts comprise a relatively narrow spectrum: they are represented mostly by CH₄, C₂H₆, C₂H₄, C₃H₈, and C₃H₆. The amount of CH₄ varies slightly, but the ratio of CH₄ to heavy hydrocarbons varies considerably because of sharp fluctuations in the abundances of heavy hydrocarbons. Accordingly, the value of the ratio of the chloroform extract of bitumen A to the alcohol-benzol extract of bitumen A varies appreciably. Rocks that underwent relatively low temperature hydration (serpentinization in peridotites,

TABLE 3
Content, Composition, and Structure of Bituminous Matter and Its Relationships With the Gaseous Phase in Individual Samples

Rock Type	Sample (Interval in cm)	Bitumen A Content, Weight Per Cent			Gaseous Phase	Gaseous-Filmy Phase	Structure of Chloroform Bitumen (A)
		Total	Chloroform Bitumen (A)	Alcohol-Benzol Bitumen (A)			
Peridotite, serpentinized	395-18-2, 63-66	0.0024	0.0018	0.0006	Associated with serpentine veins	"Sealed" by chloroform resins	"Cellular" films
Gabbro	395-17-1, 64-68	0.0024	0.0018	0.0006	Not detected	"Sealed" by chloroform resins	"Cellular" films
Dolerite	395A-63-3, 108-114	0.0060	0.0024	0.0036	Not detected	"Sealed" by chloroform resins	Finely dispersed form
Basalt, aphyric, glassy	395A-8-1, 49-52	0.0015	0.0009	0.0006	"Sealed" by chloroform bitumen (A)	In small cracks (?), recognized in disintegration of a sample up to 0.5 mm in size	"Volatile" fraction
	395A-9-2, 8-10	0.0045	0.0009	0.0036	"Sealed" by chloroform bitumen (A)	Not detected	"Volatile" fraction
Basalt, aphyric, variolitic	395A-9-2, 48-52	0.0045	0.0009	0.0036	Detected in local areas during disintegration of grains of sizes up to 0.25 mm; resembles condensate	Not detected	Inclusions in the shape of microdrops.
	395A-9-2, 81-86	0.0036	0.0018	0.0018	Detected in local areas during disintegration of grains of sizes up to 0.25 mm; resembles condensate	Not detected	Inclusions in the shape of microdrops
	395A-11-1, 80-83	0.0015	0.0009	0.0006	Detected in local areas during disintegration of grains of sizes up to 0.25 mm; resembles condensate	Not detected	Finely dispersed form
	395A-9-2, 81-86	0.0015	0.0009	0.0006	In micropores; transparent inclusions	Not detected	Finely dispersed form
Basalt, aphyric	395-16-3, 4-7	0.0073	0.0024	0.0049	"Sealed" by chloroform bitumen (A)	Not detected	"Cellular" films; in local areas
	395A-5-1, 6-10	0.0067	0.0049	0.0018	In a mineral part	Not detected	Finely dispersed form
	395A-5-1, 108-113	0.0024	0.0018	0.0018	Saturates a rock, in desorption it "boils" in chloroform	Not detected	Finely dispersed form
	395A-5-2, 10-14	0.0024	0.0018	0.0006	Manifested just as the previous one, but less pronounced	Not detected	Finely dispersed form
	395A-7-1, 129-133	0.0024	0.0018	0.0006	Saturates dark-colored minerals; "boils" in chloroform	Sporadic	Finely dispersed form
	395A-9-1, 70-73	0.0015	0.0009	0.0009	Saturates dark-colored minerals; "boils" in chloroform	Not detected	As microdrops
	395A-37-1, 50-54	0.0060	0.0024	0.0036	Not detected	Sporadic, "sealed" by chloroform bitumen (A)	Finely dispersed form
	395A-47-2, 105-110	0.0054	0.0018	0.0036	Not detected	Sporadic, "sealed" by chloroform bitumen (A)	Large areas of light and heavy fractions
	395A-50-1, 87-92	0.0027	0.0009	0.0018	Not detected	In black aggregates from small cracks "sealed" by chloroform bitumen (A)	Large areas of light fractions
	395A-51-2, 122-127	0.0054	0.0018	0.0036	Not detected	In black aggregates from small cracks "sealed" by chloroform bitumen (A)	Large areas of light fractions
395A-59-2, 43-47	0.0024	0.0012	0.0012	Not detected	Sporadic with prevalence of gaseous phase; desorption in disintegration of black aggre- gates up to 2 mm	Finely dispersed form	
Basalt porphyritic, plagioclase	395-18-2, 39-41	0.0030	0.0024	0.0006	Abundant, desorbed in disintegration	Not detected	Finely dispersed form
Basalt porphyritic plagioclase- olivine	395-19-1, 92-97	—	—	—	In micro-areas	Not detected	Finely dispersed form
	395-20-1, 35-39	0.0024	0.0018	0.0006	In micro-areas	Not detected	Finely dispersed form
	395A-13-1, 99-103	0.0036	0.0024	0.0012	In micro-areas	Not detected	Finely dispersed form
	395A-14-1, 90-98	—	0.00045	—	In micro-areas	Not detected	Finely dispersed form
	395A-14-2, 60-68	0.0045	0.0009	0.0036	By micro-areas; desorbed from undisturbed samples	Not detected	Finely dispersed form
	395A-14-3, 111-118	0.0045	0.0009	0.0036	In micro-areas	Sporadic	Finely dispersed form
	395A-15-1, 12-16	0.0018	0.009	0.009	Not detected	"Sealed" by chloroform bitumen (A); desorbed while dissolving	a) Films b) Microdrops c) "Volatile" fractions
	395A-15-1, 106-111	0.0030	0.0018	0.0012	Not detected	"Sealed" with chloroform bitumen (A)	1) "Dropped" inclusions 2) "Volatile" fractions
	395A-15-3, 72-79	0.0123	0.0074	0.0049	Not detected	"Sealed" with chloroform bitumen (A)	1) "Dropped" inclusions 2) "Volatile" fractions
	395A-16-1, 100-103	0.0018	0.0012	0.0006	Not detected	Desorbed from interbeds in disintegration of samples up to 0.02 mm	1) "Dropped" inclusions 2) "Volatile" fractions
395A-16-1, 128-131	0.0018	0.0012	0.0006	Desorbed from dark aggre- gates after release of chloroform bitumen (A)	Desorption after release of chloroform bitumen (A)	As "films" of "light" fractions	
396-15-2, 100-104	0.0067	0.0018	0.0049	Not detected	Numerous from large aggre- gates (up to 0.02 mm) after release of chloroform bitumen (A)	As large areas	
396-18-1, 140-145	0.0083	0.0034	0.0049	Desorbed from dark aggre- gates after release of chloroform bitumen (A)	Desorption with considerable delay after release of chloro- form bitumen (A)	As microfilms of "light" composition	
396-18-2, 30-35	0.0030	0.0012	0.0018	Desorbed from dark aggre- gates after release of chloroform bitumen (A)	Desorption with considerable delay after release of chloro- form bitumen (A)	As microfilms of "light" composition	
396-21-1, 70-75	0.0054	0.0018	0.0036	Desorbed from dark aggre- gates after release of chloroform bitumen (A)	Desorption with considerable delay after release of chloro- form bitumen (A)	As microfilms of "light" composition	

zeolitization, etc., in basalts) as well as coarsely crystalline rocks (gabbro), are characterized mostly by reduced bituminous matter. The total content of bituminous matter varies within one and one and a half orders of magnitude (from 0.00045 to 0.009% by weight). Morphologically, bituminous matter is represented by "filmy" forms associated with tiny cracks, by inclusions in the shape of microdrops and by dispersed-scattered forms in defects of crystals.

Thus, the chemical compositions of gases contained in basalts and their concentrations do not depend upon the chemical compositions of primary melts (if these vary within basaltic formations), but depend on the

form of volcanic manifestation (extrusive, intrusive) and the degree of epimagmatic changes of rocks (alteration, serpentinization).

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