NASA TECHNICAL MEMORANDUM NASA TM-75371

VECTOR DIAGRAM OF THE CHEMICAL COMPOSITIONS OF TEKTITES AND EARTH LAVAS

L.G. Kvasha and G.S. Gorshkov

(NASA-TM-75371) VECTOR DIAGRAM OF THE CHEMICAL COMPOSITIONS OF TEKTITES AND EARTH LAVAS (National Aeronautics and Space Administration) 17 p HC A02/MF A01 CSCL 08G
N79-10647
Unclas
G3/46 36927

Translation of: "Vektornaya diagramma khimicheskikh sostavov tektitov i zemnykh lav", Meteoritika, Vol. 20, 1961, pp. 193-203.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546 NOVEMBER 1978

VECTOR DIAGRAM OF THE CHEMICAL COMPOSITIONS OF TEKTITES AND EARTH LAVAS

L. G. Kvasha, G. S. Gorshkov

/193*

The chemical compositions of tektites (natural silica glasses) have been compared with the chemical compositions of obsidians, igneous and sedimentary rock, by a number of researchers using a variety of methods (see V. E. Barnes, 1940; G. Baker, 1959; W. F. Cassidy, 1958).

Our aim was to compare the chemical compositions of tektites and various volcanic glasses, similar in composition to tektites, by the petrochemical method of A. N. Zavaritskiy (1941, 1944, 1950). The advantage of this method is that a large number of chemical analyses of igneous rocks can be graphically compared with the help of vectors, plotted in relation to six parameters. These parameters, calculated from ratios of the main oxides given by silicate analysis, reflect the chief characteristics of igneous rock.

Material for the study was supplied by data from chemical analyses characterizing tektites of all known locations (Table 1) and data from chemical analyses of obsidians similar in chemical composition to tektites of various petrographical provinces (Table 2).

Fig. 1 shows the vector diagram plotted from numerical characteristics converted from chemical analysis data (Tables 1 and 2).

As can be seen from the diagram and tables, the majority of starting points of vectors are located along the SB axis or near it and a band of almost constant width is formed. The range and shape of the vector cluster as a whole specify the chemical composition of tektites as strongly supersaturated and supersaturated with silica, as well as very poor and poor in alkalis (a is not over 4). The length and direction (sloped to the left) of the vectors specify them as supersaturated with silica with a relatively high basicity, fluctuating in wide limits (b from 5 to 15).

Five vectors deviate from the general band in high alkalinity — 1 indochinite, 2 billitonite, 1 javaite and 1 americanite (inclusion of the latter

---

*Numbers in margin indicate pagination in original foreign text.

among tektites proper is subject to doubt).

The cluster of vectors for chemical compositions of tektites from various locations is gradually shifted along the SB axis and forms fields which partially overlap, but not sharply isolated groups. These fields are shifted in the following order of increasing basicity: Vltavins (moldavites) — indochinites and australites — billitonites — bediasites — Ivory Coast tektites.

We must note the group of vltavins (moldavites) distinguished by the prevalence of potassium among alkalis. /201

The variation curve of the chemical compositions of tektites (TT), determined by the position of initial points of vectors, is characterized by its proximity to the SB axis and its weak slope toward this axis. It proceeds lower (from point A) to the variation curve of feldspar achondrites (see L. G. Kvasha, 1958, 1959) which are distinguished by the same character.

Earth lavas in a petrochemical respect have been quite well investigated. Their analyses number in the thousands. The initial points of vectors, representing their chemical compositions, form very definite bands. These bands, reflecting change in the composition of lavas during the course of normal crystallization-gravitation differentiation of magma, can be expressed in variation curves. A certain variation curve corresponds to each type of lava.

In Fig. 1 is plotted the variation curve of chemical compositions of lavas from Japanese volcanos (JJ), converted to the variation curve of chemical compositions of Pelee type lavas, according to the method of A. N. Zavaritskiy (1950). It represents calc-alkali lavas of island chains and is closest to the SB axis of all variation curves of earth lavas. Numerical characteristics of average types of Japanese lavas, according to the data of S. Taneda (1952) are given in Table 3.

The vector cluster of obsidians is located to the right of the variation curve JJ close to the SA axis and is slightly elongated in the direction of this axis. This cluster shape indicates significant fluctuations of alkalinity in obsidians, as they belong to various petrochemical associations. The length and direction of the majority of vectors correspond to the normal type of chemical compositions (sloped toward the right); about 1/3 of the vectors show a sharp slant to the right, i.e. potassium predominates in their femic part (flatter vectors). However, about 1/4 of the total number of vectors

Table 1

No.	Tektites and their locations	Numerical characteristics*										Q	a/c	Source (second is analyst)
		main				secondary								
		a	c	b	s	a'	f'	m'	c'	n	t			
	Vltavins (moldavites) Czech.													
1	Bohemia	3.2	3.2	5.1	38.5		42.3	57.7		0		67.4	1	J. Hanamann (1894)
2	" "	5.6	2.4	5.8	86.2	26.3	29.5	44.2		13.6	0.3	58.8	2.38	R. Novaček (1932)
3	Moravia	5.3	2.2	6.0	86.5	40	15	45		19.5	0.66	60.2	2.4	A. Lacroix (1932) F. Raoult
4	Bohemia	4.4	4.1	6.0	85.5		35	60	5	18.6	0.3	58.1	1.0	R. Novacek (1932)
5	Cheske-Budejovice	4.3	2.4	6.3	87.0	44.5	18.2	37.4		29.0	0.66	63.0	1.75	C. John (1899)
6	Bohemia	5.6	2.0	7.2	85.2	38.5	29.0	32.5		22.0	57.2	57.2	2.8	A. Lacroix (1932) F. Raoult
7	" "	3.3	2.4	7.6	86.7	56.1	23.2	20.7		11.5		64.4	1.4	C. John (1889)
8**	Moravia	5.1	2.8	7.6	84.5	42.5	22.0	35.0		20	0.37	56.0	1.7	R. Novaček (1932)
9	Bohemia	4.3	3.5	7.7	84.5	65.4	30.4	4.2		15		56.9	1.23	C. John (1889)
10	Moravia	6.8	1.3	8.5	83.4	58.9	22.5	18.6		21.5	0.5	51.9	5.2	R. Novaček (1932)
11	" "	5.7	1.4	10.2	82.7	55.2	22.1	22.7		24	1.35	52.6	4.1	A. Lacroix (1932) Ludwig
12	" "	4.9	1.8	11.3	82.0	55.3	25.4	19.3		15		62.4	2.6	C. John (1899)
13**	" "	4.9	2.1	11.4	81.6	52.0	27.7	20.3		25.6		51.8	2.3	C. John (1899)
14	Bohemia	5.4	1.4	11.8	81.4	62.8	22.9	14.3		30.2		50.6	3.8	C. John (1899)
	Indochinites Indochina and So. China													
15	Cambodia	6.6	0.8	7.3	85.3		57.6	28.8	13.6	52	1.0	56.6	8.2	A. Lacroix (1935) F. Raoult
16	VietNam	6.6	3.0	7.5	82.9	46.8	0.4	52.8		55	0.9	49.6	2.2	A. Lacroix (1935) F. Raoult

/194

Table 1 (continuation)

No.	Tektites and their locations	Numerical characteristics*										Q	a/c	Source (second is analyst)
		main				secondary								
		a	c	b	s	a'	f'	m'	c'	n	t			
17	So. China, Haitan	6.9	5.2	8.6	79.3		57.0	36.1	6.9	45	1.1	39.6	1.25	A. Lacroix (1930) F. Raoult
18***	Cambodia	8.9	2.8	9.3	79.0	12	45	43		57	0.8	37.4	3.1	A. Lacroix (1929) F. Raoult
19**	Laos	7.4	3.6	9.9	78.8	15.4	52.0	32.6		47	1.1	39.5	2.1	A. Lacroix (1930) F. Raoult
20	Thailand (Siam)	8.1	0.3	9.9	81.7		36.1	34.7	29.2	45	0.7	46.9	2.7	C. M. Koomans (1938)
21	Malacca	7.6	4.1	10.0	78.3	18.6	46.0	34.5		56.5	0.8	37.3	1.8	A. Lacroix (1932) F. Raoult
22**	Laos	7.2	3.2	10.2	79.4	25.5	41.5	33.0		50	1.1	41.2	2.2	A. Lacroix (1935) F. Raoult
23	Thailand	6.9	2.9	10.4	79.8	33.5	43.8	22.7		57.4	0.8	42.9	2.4	A. Lacroix (1935) F. Raoult
24	So. China	5.2	3.8	11.0	80.0	28.6	41.7	29.7		50.2	1.0	45.8	1.4	A. Lacroix (1935) F. Raoult
25	Cambodia	7.1	2.6	11.4	78.9	27.3	41.5	31.2		60	0.9	41.0	2.7	A. Lacroix (1935) F. Raoult
26**	Viet Nam	6.3	2.6	12.2	78.9	29.3	39.8	30.9		53	1.05	42.6	2.5	A. Lacroix (1935) F. Raoult
27	So. China	6.0	3.5	12.3	78.2	36.6	37.2	30.9		50	1.0	40.9	1.7	A. Lacroix (1935) F. Raoult
28	Viet Nam	5.7	2.6	15.9	75.8	31.4	52.2	16.4		51	0.9	37.6	2.2	A. Lacroix (1935) F. Raoult
	Australites Australia and Tasmania													
29	Northern Australia	5.4	2.8	7.8	84.0	21.4	46.0	32.6		50	0.8	54.4	1.9	H. S. Summers (1909) G. A. Ampt
30	Tasmania	4.9	3.4	8.4	83.3		48.4	36.3	15.3	44	0.7	63.4	1.44	F. W. Clarke (1904) W. F. Hillebrand

/195

Table 1 (continuation)

No.	Tektites and their locations	Numerical characteristics*										Q	a/c	Source (second is analyst)
		main				secondary								
		a	c	b	s	a'	f'	m'	c'	n	t			
	Australites Australia and Tasmania													
31	Victoria	4.9	3.0	9.6	82.5	36.0	39.4	24.6		50	0.6	52.2	1.6	H. S. Summers (1909) G. A. Ampt
32	" "	5.7	3.7	11.5	79.1	31.7	40.6	27.7		54	0.8	43.1	1.5	H. S. Summers (1909) G. A. Ampt
33	Western Australia	5.7	3.5	13.3	77.5	32.5	38.6	28.9		48	0.9	40.1	1.6	A. Lacroix (1932) A. Hall
34	Tasmania	6.5	3.7	14.0	75.8	37.7	33.7	28.6		43	0.8	34.9	1.8	W. F. Hillebrand (1910)
	Billitonites Billiton, Java, Borneo													
35	Billiton	9.0	3.0	9.0	79.0		57	43		57		37	3	R. D. Verbeek (1897) Brunck
36	" "	6.8	4.7	10.8	77.7	4.9	55.5	39.6		53	1.2	37.1	1.4	A. Lacroix (1930) F. Raoult
37	" "	8.6	3.5	10.9	77.0		53.5	38.7	7.8	60		32.7	2.4	F. E. Suess (1900) C. John
38	Java	5.4	2.9	11.7	80.0	25.4	40.0	34.6		43	0.9	46.3	1.8	F. Heide (1939) P. Wagner
39	"	5.7	3.4	13.8	77.1	23.5	42.0	34.5		61	0.6	39.4	1.6	C. M. Koomans (1938)
40	Borneo	14.3	1.4	14.2	70.1		31.0	41.5	27.5	82.7	1.1	27.2	10.2	A. Lacroix (1932) F. Raoult
41	" "	6.2	2.6	14.7	76.5	38.5	35.8	25.7		51	1.1	38.0	2.4	F. P. Müller (1945) Hinden

/196

Table 1 (continuation)

No.	Tektites and their locations	Numerical characteristics*										Q	a/c	Source (second is analyst)
		main				secondary								
		a	c	b	s	a'	f'	m'	c'	n	t			
Philippinites, Rizalites Philippines														
42	Luzon	6.8	4.7	9.3	79.2		52.8	46.5	0.7	51	0.9	40.1	1.4	T. Hodge-Smith (1932) H. P. White
43**	"	5.9	4.1	11.2	78.8	31	37	32		57	0.8	41.7	1.4	C. M. Koomans (1938)
44**	"	5.6	3.9	11.9	78.6	21.0	40.9	38.1		44	1.8	36.5	1.4	A. Lacroix (1931) F. Raoult
45	"	6.1	3.4	11.9	78.6	23.3	37.0	39.7		57.5	1.8	41.6	1.8	C. M. Koomans (1928)
46**	"	6.2	3.2	12.2	78.4	26.6	37.7	35.7		48	1.0	41.2	1.9	F. Heide (1938) P. Wagner
47	"	5.8	3.4	14.2	76.6	19.2	40.2	40.6		58	0.6	38.2	1.7	C. M. Koomans (1938)
Americanites So. America,														
48	Peru	11.8	0.9	13.3	74.0	91.8	6.7	1.5		60.1	23	23.5	14.2	G. Linck (1926)
Ivory Coast Tektites Western Africa														
49	Ivory Coast	3.7	1.8	15.2	79.3	41	23	36		70	0.6	49.4	2.0	A. Lacroix (1934) F. Raoult
50	" "	7.1	1.6	18.9	72.4	45.4	30.8	23.8		61.7	0.9	29	4.4	A. Lacroix (1934) F. Raoult
51	" "	5.2	2.2	21.2	71.4	49.7	25.4			55	0.9	30.2	2.35	A. Lacroix (1940) F. Raoult

/197

Table 1 (continuation)

No.	Tektites and their locations	Numerical characteristics*										Q	a/c	Source (second is analyst)
		main				secondary								
		a	c	b	s	a'	f'	m'	c'	n	t			
	Bediasites, North America													
52	Texas, USA	5.4	0	15.4	79.2	67.6	20.7	11.7		52	0.7	47.6		V. E. Barnes (1940) F. A. Gonyer (1940)
53	" "	4.7	0.1	20.3	75.0	68.6	20.9	10.5		54	0.9	40.4	47	V. E. Barnes (1940) F. A. Gonyer

* Numerical characteristics are arranged in order of increasing b within geographical groups.

** Vectors of chemical compositions of tektites No. 8, 13, 19, 22, 26, 43, 44 and 46, as respectively equal to the vectors of chemical compositions of tektites No. 6, 12, 21, 23, 27, 46, 24 and 32, 45, 26 and 27, are not plotted on the diagram.

*** Vector of the chemical composition of tektite No. 18 is not plotted on the CSB plane as it is almost coincident with vectors No. 31 and 35.

Table 2

No.	Obsidians from various geographic regions	Numerical characteristics*									Q	a/c	Source
		main				secondary							
		a	c	b	s	a'	f'	m'	c'	n			
	Islands of the Atlantic ocean												
1	Ascension	16.3	2.7	1.5	79.5		48	9	43	67	23.6	6.0	R. Reinisch (1912)
2	Canaries	15.6	1.2	4.1	79.1	22	67	11		54	25.8	13.0	K. Fritsch, W. Reiss (1868)
3	" "	26.0	1.3	4.4	69.3		93		7	73	15.7	20.0	K. Fritsch, W. Reiss (1868)
4	Azores	20.3	1.6	7.7	70.4	42	50	8		65	1.4	12.7	P. Esenwein (1929)

Table 2 (continuation)

No.	Obsidians from various geographic regions	Numerical characteristics*									Q	a/c	Source
		main				secondary							
		a	c	b	s	a'	f'	m'	c'	n			
5	Canaries	20.5	1.9	12.2	65.4	20	75	5		72	12.1	10.8	K. Fritsch, W. Reiss (1868)
	Islands of the Mediterranean												
6	Sardinia (Monte Arci)	14.7	0.9	1.9	82.5	7	75	18		54	34.7	16.4	H. Washington (1913$_1$)
7	Lipari	15.8	0.5	2.2	81.5		82	3	15	56	30.9	31.6	A. Bergeat (1900)
8	"	15.4	0.4	2.4	81.8		76	8	16	56	32.0	38.6	A. Bergeat (1900)
9	"	14.6	0.8	3.0	81.6		71	11	18	56	33.2	18.2	A. Bergeat (1900)
10	Pantelleria	16.9	3.0	3.4	76.2		80	14	6	60	16.1	5.6	H. Washington (1913$_2$)
11	Vulcano	16.6	0	5.3	78.1		36	21	43	59	23.0	0	A. Lacroix (1908)
	Japan												
12	Hokkaido	12.6	2.3	2.0	83.1	14	48	38		51	38.7	5.5	T. Murase (1958)
13	Honshu	11.9	1.1	3.4	83.6	58	31	11		50	40.3	9.7	T. Murase (1958)
	No. America												
14**	Lake Mono	14.9	0.5	2.2	82.4		59	23	18	57	34.5	29.8	J. S. Diller (1898)
15	Yellowstone	12.9	1.3	2.9	82.9		21	62	17	55	38.7	9.9	A. Hague, J. P. Iddings, W. Weed, et al. (1899)
16	" "	13.9	0.9	3.4	81.8		53	38	9	60	34.9	15.5	A. Hague, J. P. Iddings, W. Weed, et al. (1899)
17**	" "	13.2	0.9	4.7	81.2		64	32	4	61	35.1	14.7	A. Hague, J. P. Iddings, W. Weed, et al. (1899)
18	" "	11.5	1.0	4.0	82.6		45	45	10	59	41.2	11.5	A. Hague, J. P. Iddings, W. Weed et al. (1899)

Table 2 (continuation)

No.	Obsidians from various geographic regions	Numerical characteristics*									Q	a/c	Source
		main				secondary							
		a	c	b	s	a'	f'	m'	c'	n			
	Iceland												
19		12.8	32	2.5	82.5		62	11	27	66	37.2	5.8	F. Wolff (1931)
20		13.0	1.9	4.0	81.1		38	10	52	75	34.3	6.8	F. Wolff (1931)
21		17.1	1.0	5.2	76.6		64	18	18	64	18.2	17.1	F. E. Wright (1915)
	Africa												
22	Kenya	9.8	8.1	2.6	79.5		n'=67	5	28	48	31.3	1.2	A. Holmes, H. F. Harwood (1936)
23	"	14.1	9.4	2.6	73.9		n'=8	24	68	52	10.2	1.4	A. Holmes, H. F. Harwood (1936)
	Asia												
24**	Armenia	16.8	0.4	2.5	80.3		67	10	23	59	26.6	42.0	A. S. Ginzberg (1934)
25	Marekanka R. near Okhotsk	12.8	0.7	4.6	81.9	65	27	8		63	37.5	18.3	Unpublished analysis I. I. Tovarova (1960)
26	Caucasus	10.9	1.4	5.3	82.4	70	19	11		45	41.6	7.8	N. N. Chirvinskiy (1934)

* Numerical characteristics are arranged in order of increasing b within petrographical provinces coinciding with these geographical regions with the exception of obsidians No. 24, 25 and 26.

** Vectors of chemical compositions of obsidians No. 14, 17, 24 on CSB plane are not plotted as they are coincident, respectively, with vectors of No. 7, 18, 8.

/199

Table 3

Average types of lavas of Japan	Numerical characteristics									Q	a/c	Source	
	main				secondary								
	a	c	b	s	a'	f'	m'	c'	n				
Andesite	8.4	8.0	12.7	70.9		56	38	6	75	17	1.0	S. Taneda	(1952)
Dacite	9.1	6.7	8.2	76.0		66	34	0	72	27.1	1.4	S. Taneda	(1952)
Rhyolite	8.3	2.0	5.4	84.3	58	41	1		79	50	4.1	S. Taneda	(1952)

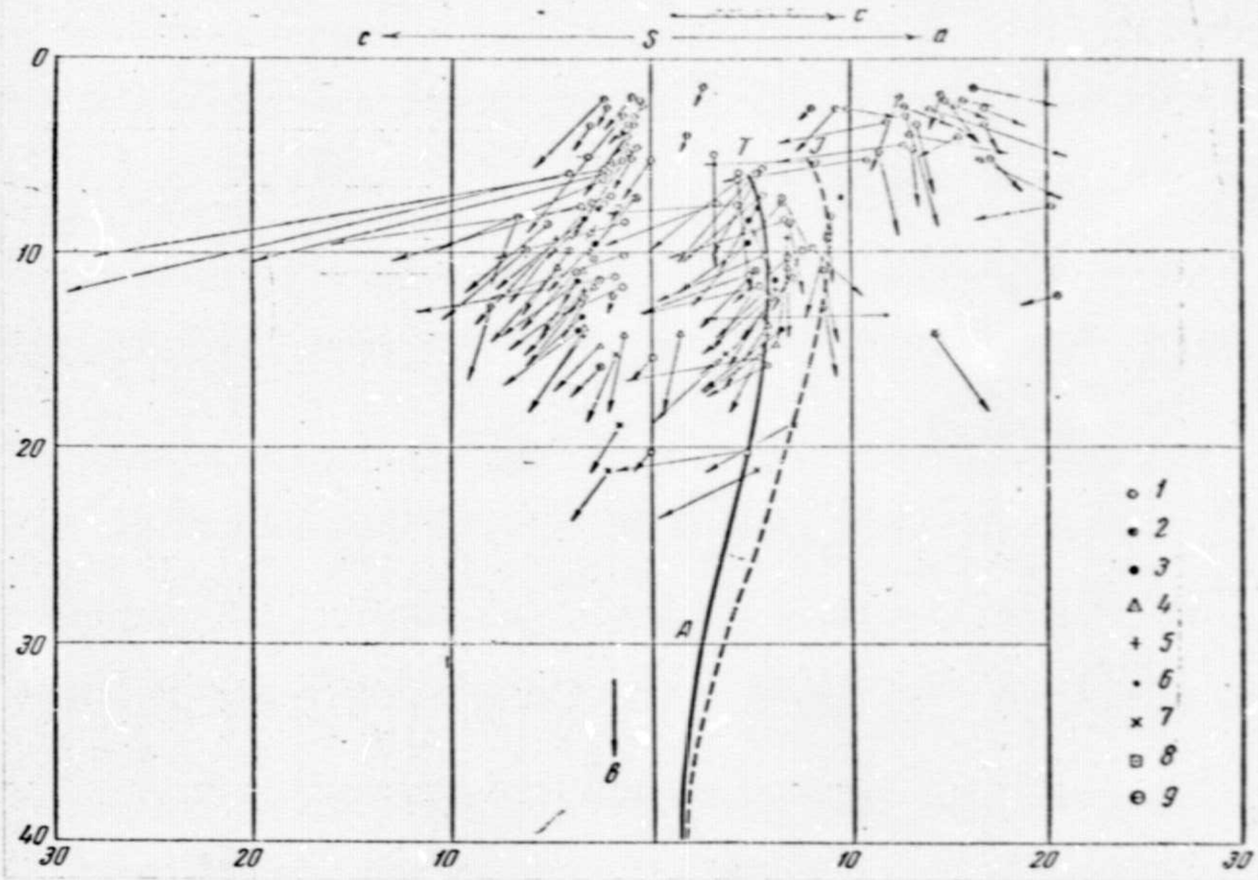

Fig. 1. Vector diagram of chemical composition of tektites and glass earth lavas
Legend: 1 — Vltavins (moldavites); 2 — indochinites; 3 — australites; 4 — billitonites; 5 — philippinites; *

---

*Translator's Note: Illegible in the foreign text.

are related to compositions supersaturated with silica (vectors slope to the left).

From the diagram it is evident[1] that the vector fields of tektites and obsidians are clearly delimited and, what is more, the cluster of vectors of tektites is located to the left of the extreme variation curve of earth lavas representing a series of calc-alkali lavas of island chains. Further, the chemical compositions of tektites differ from those of obsidians in less alkalinity (their numerical characteristic a fluctuates between 4-6 while for obsidians it is usually over 8) and the predominant supersaturation with silica, even in more basic varieties. An increased TiO_2 content is noted (parameter t about 1). In addition, the character of parameter b is generally more basic — from 5 to 15 (instead of 3-5 in obsidians), corresponding to dacites and andesites rather than liparites.

Analysis of the diagram leads to the conclusion that tektites are not earth lavas. Moreover, the variation curve of the chemical compositions of tektites, qualitatively similar to the closest variation curve of earth lavas, is a continuation of the variation curve of the chemical compositions of feldspar achondrites, forming a long series similar to the natural series of individual types of earth lavas. Therefore, tektites can be considered as products of crystallization-gravitation differentiation of feldspar achondrites, in their way lavas in the same way as obsidians and andesites are products of differentiation of earth basalts. In this case it must be assumed that tektites and /202 achondrites originated in the same heavenly body of sufficient size, in which processes were occurring similar to the processes and phenomena of vulcanism on earth.

REFERENCES

1. Ginzberg A. S. Petrografiya respubliki Armenii. Petrografiya SSSR. (Petrography of the Republic of Armenia. USSR Petrography). Series No. 2, 1934.

2. Zavaritskiy A. N. Pereschet khimicheskikh analizov izverzhennykh gor-

---

[1] Only the ASB plane is considered, as in CSB projection the initial points of the vectors of tektites and obsidians form a combined field.