**MEAN COMPOSITION OF FELDSPAR IN HED METEORITES AND IN PROTOPLANET VESTA.**
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**Introduction:** Feldspars are important minerals common in terrestrial and in extraterrestrial rocks. Data on the mean composition of feldspar in various meteorites, mainly chondrites and achondrites have been recently collected and analysed [1]. In our previous and present studies the mean composition of meteorites was the main source of data on feldspar, since the mean bulk elemental composition of meteorites contains important data on mean composition of various minerals, including plagioclase feldspar. HED meteorites and their parent body belong to very interesting and important extraterrestrial objects. Our intersts include also thermal properties of meteorites, asteroids and terrestrial planets. Specific heat capacity, heat capacity, and thermal capacity of Vesta have been recently estimated [2]. Dawn mission data enriche our knowledge on 4 Vesta, which is considered to be a parent body of HED meteorites. The aim of the paper was to determine and analyze the mean composition of feldspar in HED meteorites and in protoplanet Vesta.

**Results:** Data on the mean bulk elemental composition of HED meteorites and on predicted composition of HED parent body were used to calculate albite ($NaAlSi_3O_8$), anorthite ($CaAl_2Si_2O_8$) and orthoclase ($KAlSi_3O_8$) content. To determine albite (Ab), anorthite (An), and orthoclase (Or) content in feldspar the following relationships derived by Szurgot [1] were used:

$$Ab=100\cdot 2\cdot Na/[Al+Na+K], \quad (1)$$

$$An=100\cdot [Al-Na-K]/[Al+Na+K], \quad (2)$$

$$Or=100\cdot 2\cdot K/[Al+Na+K], \quad (3)$$

where Ab, An, and Or are expressed in mol%, and sodium (Na), potassium (K) and aluminum (Al) contents in at%. To derive eqs.(1)-(3) it was assumed that sodium is present only in albite, potassium only in orthoclase, and aluminum only in feldspar. Anorthite calcium content is expressed by Al content.

When sodium, potassium, and aluminum content are given in weight percent instead of atomic percent the modified equations are used:

$$Ab=100\cdot 2\cdot (Na^*/Al^*)\cdot (M_{Al}/M_{Na})/D, \quad (4)$$

$$An=100\cdot C/D, \quad (5)$$

$$Or=100\cdot 2\cdot (K^*/Al^*)\cdot (M_{Al}/M_K)/D, \quad (6)$$

where C and D are represented by

$$C=[1-(Na^*/Al^*)\cdot (M_{Al}/M_{Na})-(K^*/Al^*)\cdot (M_{Al}/M_K)], \quad (7)$$

$$D=[1+(Na^*/Al^*)\cdot (M_{Al}/M_{Na})+(K^*/Al^*)\cdot (M_{Al}/M_K)], \quad (8)$$

where $M_{Al}$, $M_{Na}$, and $M_K$ represent elemental atomic weight of aluminum, sodium, and potassium, and Na*, Al*, and K* are sodium, aluminum and potassium content in wt%.

Our calculations reveal mean composition of feldspar determined for the three achondrite groups: eucrites Ab11An89Or0.6, howardites Ab10An89Or0.5, and diogenites Ab17An81Or1.4 (Tables 1-3). The mean composition of feldspar estimated by various models of HED parent body is Ab10An90Or0.5 (Table 4), and is very close to the eucrite mean feldspar, and to the howardite mean feldspar (Tables 1, 2). The range of anorthite content in eucrites amounts to An78-96, in howardites An87-91, and in diogentes An50-96 (Tables 1-3). This means that our data reveal for HED achondrites the range of anorthite content An50-96. The range of albite content in eucrites Ab4-22, in howardites Ab8-12, and in diogentes Ab4-50. For the whole HED group we have Ab4-50, and orthoclase content is equal to Or0-7, as for diogentes. For eucrites we have Or0-1.8, and for howardites Or0-1.

**Table 1** Mean composition of feldspar in eucrites.

| Meteorite name | Feldspar | |
|---|---|---|
| Petersburg | $Ab_{21.8}An_{78.2}$ | Ab22An78 |
| Chervony Kut | $Ab_{11.9}An_{86.3}Or_{1.8}$ | Ab12An86Or2 |
| Nuevo Laredo | $Ab_{12.8}An_{86.4}Or_{0.8}$ | Ab13An86Or1 |
| HaH 286 | $Ab_{12.4}An_{87.6}$ | Ab12An88 |
| Stannern | $Ab_{11.4}An_{87.8}Or_{0.8}$ | Ab11An88Or1 |
| Petersburg | $Ab_{11.1}An_{88.3}Or_{0.6}$ | Ab11An88Or1 |
| Pasamonte | $Ab_{10.6}An_{88.7}Or_{0.7}$ | Ab10An89Or1 |
| Y 74450 | $Ab_{9.5}An_{89.0}Or_{1.5}$ | Ab10An89Or1 |
| Sioux County | $Ab_{9.8}An_{89.8}Or_{0.5}$ | Ab10An90 |
| NWA 4039 | $Ab_{8.6}An_{91.4}$ | Ab9An91 |
| Serra de Mage | $Ab_{4.5}An_{94.5}Or_{0.1}$ | Ab5An95 |
| ALH A81001 | $Ab_{3.9}An_{95.8}Or_{0.3}$ | Ab4An96 |
| **Range** | $Ab_{3.9-21.8}An_{78.2-95.8}Or_{0-1.8}$ | |
| | | Ab4-22An78-96Or0-2 |
| **Mean** | $Ab_{10.7\pm4.5}An_{88.7\pm4.4}Or_{0.6\pm0.6}$ | |
| | Ab11±5An89±5Or0.6±0.6 | |

Individual meteorites reveal mean composition of feldspar: i) eucrites: Chervony Kut Ab12An86Or2, Pasamonte Ab10An89Or1, Yamato 74450 Ab10An89Or1, Stannern Ab11An88Or1, Sioux County Ab10An90, Nuevo Laredo Ab13An86Or1, Petersburg Ab11-22An78-88Or0-1, HaH 286 Ab12An88, NWA 4039 Ab9An91, Serra de Mage Ab5An95, ALH A81001 Ab4An96; ii) howardites: Bununu Ab12An87Or1, Malvern Ab11An88Or1 Kapoeta Ab10.5An89Or0.5, Bholghati Ab10An89Or0.6, Frankfort Ab10An90Or0.5, Yurtuk Ab10An90, Y 7308 Ab10An90Or0.4, Y 82049 Ab8An91Or0.5; iii) diogenites: NWA 4965 Ab50An50, Ellemeet Ab31An63Or6, Tatahouine Ab16An83Or1, Shalka Ab20An79Or1, Johnstown Ab4-37An56-96Or0-7, Y 791200 Ab10An90, Y 75032 Ab9An90-91Or0-0.4, NWA 1461 Ab8An92, LAP 91900 Ab6An94.

**Table 2** Mean composition of feldspar in howardites.

| Meteorite name | Feldspar | |
|---|---|---|
| Bununu | $Ab_{11.8}An_{87.4}Or_{0.8}$ | Ab12An87Or0.8 |
| Malvern | $Ab_{11.5}An_{87.5}Or_{1.0}$ | Ab11An88Or1 |
| Kapoeta | $Ab_{10.5}An_{89.0}Or_{0.5}$ | Ab10.5An89Or0.5 |
| Kapoeta | $Ab_{10.4}An_{89.1}Or_{0.5}$ | Ab10.5An89Or0.5 |
| Bholghati | $Ab_{10.3}An_{89.1}Or_{0.6}$ | Ab10An89Or0.6 |
| Frankfort | $Ab_{9.9}An_{89.6}Or_{0.5}$ | Ab10An90Or0.5 |
| Yurtuk | $Ab_{10.0}An_{90.0}$ | Ab10An90 |
| Y 7308 | $Ab_{9.5}An_{90.1}Or_{0.4}$ | Ab10An90Or0.4 |
| Y 82049 | $Ab_{8.3}An_{91.2}Or_{0.5}$ | Ab8An91Or0.5 |
| **Range** | $Ab_{8.3-11.8}An_{87.4-91.2}Or_{0-1}$ | |
| | Ab8-12An87-91Or0-1 | |
| **Mean** | $Ab_{10.2\pm1.0}An_{89.2\pm1.2}Or_{0.5\pm0.3}$ | |
| | Ab10±1An89±1Or0.5±0.3 | |

**Table 3** Mean composition of feldspar in diogenites.

| Meteorite name | Feldspar | |
|---|---|---|
| NWA 4965 | $Ab_{50.5}An_{49.5}$ | Ab50An50 |
| Johnstown | $Ab_{36.4}An_{56.3}Or_{7.3}$ | Ab37An56Or7 |
| Ellemeet | $Ab_{31.2}An_{62.6}Or_{6.2}$ | Ab31An63Or6 |
| Shalka | $Ab_{19.7}An_{79.4}Or_{0.9}$ | Ab20An79Or1 |
| Tatahouine | $Ab_{15.9}An_{82.7}Or_{1.4}$ | Ab16An83Or1 |
| Y 791200 | $Ab_{10.0}An_{90.0}$ | Ab10An90 |
| Y 75032 | $Ab_{9.2}An_{90.4}Or_{0.4}$ | Ab9An90Or0.4 |
| Y 75032 | $Ab_{9.4}An_{90.6}$ | Ab9An91 |
| NWA 1461 | $Ab_{7.9}An_{92.1}$ | Ab8An92 |
| Johnstown | $Ab_{7.0}An_{92.6}Or_{0.4}$ | Ab7An93Or0.4 |
| LAP 91900 | $Ab_{6.3}An_{93.7}$ | Ab6An94 |
| Johnstown | $Ab_{4.3}An_{95.7}Or_{0.4}$ | Ab4An96Or0.4 |
| **Range** | $Ab_{4.3-50.5}An_{49.5-95.7}Or_{0-7.3}$ | |
| | Ab4-50An50-96Or0-7 | |
| **Mean** | $Ab_{10.2\pm1.0}An_{89.2\pm1.2}Or_{0.5\pm0.3}$ | |
| | Ab17±15An81±16Or1.4±2.5 | |

**Table 4** presents the mean composition of Vestan feldspar resulting from various models of Vesta.

**Table 4** Mean composition of feldspar in Vesta calculated for mean bulk composition of HED parent body assumed in various models.

| Composition data | Feldspar | |
|---|---|---|
| RD97 (CM) | $Ab_{11.3}An_{86.2}Or_{2.5}$ | Ab11An86Or2.5 |
| Mason 67 | $Ab_{13.4}An_{86.6}$ | Ab13An87 |
| RD97 (L) | $Ab_{11.7}An_{87.8}Or_{0.5}$ | Ab12An88Or0.5 |
| RD97 (CI) | $Ab_{11.3}An_{88.1}Or_{0.6}$ | Ab11An88Or0.6 |
| RD97 (EH) | $Ab_{11.2}An_{88.4}Or_{0.4}$ | Ab11An88Or0.4 |
| Jones 84 | $Ab_{10.6}An_{88.8}Or_{0.6}$ | Ab11An89Or0.6 |
| DW80 | $Ab_{10.4}An_{89.0}Or_{0.6}$ | Ab10An89Or0.6 |
| CD77Met | $Ab_{7.4}An_{92.6}$ | Ab7An93 |
| CD77 | $Ab_{7.0}An_{93.0}$ | Ab7An93 |
| Morgan78 | $Ab_{6.4}An_{93.3}Or_{0.3}$ | Ab6An93Or0.3 |
| Hertogen77 | $Ab_{6.6}An_{93.4}$ | Ab7An93 |
| **Range** | $Ab_{6.4-13.4}An_{86.2-93.4}Or_{0-2.5}$ | |
| | Ab6-13An86-93Or0-3 | |
| **Mean** | $Ab_{9.8\pm2.4}An_{89.8\pm2.8}Or_{0.5\pm0.7}$ | |
| | Ab10±2An90±3Or0.5±0.7 | |

Source of data in Table 4: RD97 are Righter and Drake data [3], Jones 84 are Jones data [4], Mason 67 are Mason data [5], DW80 are Dreibus and Wanke data [6,7], CD77 are Consolmagno and Drake data [8], Morgan 78 are Morgan et al. data [9], and Hertogen77 are Hertogen et al. data [10].

**Conclusions:** The mean composition of feldspar in HED parent body (Ab10An90Or0.5) is close to the eucrite and howardite composition of feldspar. This is expected since plagioclase feldspar is located mainly in eucrites and howardites.

**References:** [1] Szurgot M. (2013) *76th AMMS*, Abstract #5001. [2] Szurgot M. (2013) *76th AMMS*, Abstract #5264. [3] Righter K and Drake M. *Meteoritics & Planet. Sci.*, *32*, 929-944. [4] Jones J.H. (1984) *Geochim. Cosmochim. Acta*, *48*, 641-648. [5] Mason B. (1967) *American Scientist*, *51*, 429-455. [6] Dreibus G. and Wanke H. (1980) *Z. Naturforsch. 35a*, 204-216. [7] Ruzicka A. et al. (1997) *Meteorit. Planet. Sci. 32*, 825-840. [8] Consolmagno G. J. and Drake M. J. (1977) *Geochim. Cosmochim. Acta 41*, 1271-1282. [9] Morgan J.W. et al. (1978) *Geochim. Cosmochim. Acta*, *42*, 27-38. [10] Hertogen J. et al. (1977) *Bull. Amer. Astron. Soc. 9*, 458-459.